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A Method of Determining Resultant Input from Individual Duty Cycles and of Determining Temperature Rating

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Review of the Subject.—*Before it is possible to put a group of motors into service, it is necessary to provide means for generating and transmitting the energy which probably will be required to operate them. To select the proper and economical capacity of such generating and transmitting equipment, requires that some reasonably correct estimate be made of the probable amount and probable time distribution of the combined load due to the motors when in service.*

When the motors all operate in a definite sequence on a definite time schedule the problem is simple. But, in the great majority of cases, such as tool, hoist, elevator or traction drive, the motors comprising the group do not in general operate in any such connected sequence. They operate more or less at random.

It is usual to estimate the probable load under such conditions of random, or approximately random, operation by guess work controlled only by experience and by comparison with load records obtained from similar installations already in operation. In general this method of estimating from records is not satisfactory.

In the first place such records, if sufficient for the purpose, are expensive to obtain and are not always available. In the second place, they are generally records of effects and not of causes. Whereas, as is shown in the paper, if the causes are known, the effects can be foretold with surprising accuracy. If certain average duty cycle characteristics of the motor application are known, as they must be known to make an intelligent selection of the motors for the required duty, then, by a simple application of the formulas of probabilities, it is possible to determine the characteristics of the energy input to any group of such motors.

No very great refinement in determining the average duty cycle for the individual motors in the group is required, for, if the number of motors or the number of observations of actual duty cycles be reasonably large, the average deviation from the mean will be small.

It is found that the method proposed gives calculated results that check quite closely with measured results. Not only can the average input, and from this the probable power consumption in kilowatt-hours be determined, but also the r. m. s. or heat generating value of the load as well as the probable amount and frequency of the peaks. Furthermore, data may be obtained for plotting in advance the most probable time distribution of load similar to a graphic instrument record.

The whole method is based on a determination of the average value of the ***operating factor*** *for the group of motors under consideration. The operating factor is the ratio of the average time any motor is running to the average duty cycle period. The operating factor may be averaged over any group of motors or, its average value may be determined from a graphic instrument record, such as obtained from a graphic wattmeter or ammeter. The value of the average operating factor is a better measure of the variations of load or input to a group of motors than either demand factor or diversity factor. In fact, it is shown that the value of the demand factor is generally meaningless and misleading.*

The value of the operating factor seems to lie within fairly narrow limits over numerous cases of the same kind of motor application. The demand factor does not possess this character.

Having thus established a method of rating the current-carrying and protective devices handling the input to a group of motors, it is necessary to establish a method of similarly rating conductors and protective devices handling the input to individual motors in the group. In other words, it is necessary to determine the heating value of any given intermittent duty cycle in terms of a continuous duty having equal heating value. The ratio between these two duties is found as a ratio of duty cycle factors expressed in terms of the operating factor for the individual duty cycle. In the continuous duty the operating factor is unity, and the duty cycle factor is also unity.

Since current-carrying devices are generally temperature rated in terms of continuous duty, it becomes possible to re-rate all such devices for other than continuous duty by operations performed on the duty cycle factors for the non-continuous or intermittent duty cycles. In this way various time ratings may be established for conductors, fuses, motors, generators, etc.

The resulting calculated time ratings for conductors prove to be very nearly the same as ratings established for the same times by actual tests.

The resulting calculated time ratings for fuses indicate how very narrow is the possible field for fuses as protective devices where continuous heavy overloads are not to be passed without rupture. In general it is impossible to use one set of fuses to protect a motor against more than 25 per cent continuous overload unless the starting peak is almost negligible. The result is quite in accord with general observation and test. It is shown that the underwriter's method of selecting fuses generally introduces a hazard rather than a safeguard.

NEW TERMS. Two new terms have been introduced, the ***operating factor*** *and the* ***duty cycle factor.*** *The operating factor not only determines the ratio of average load to total wired load, but also determines the ratio of r. m. s. load to the average load, as well as the amount, duration and frequency of peaks. In a sense, it is also a measure of operating efficiency.*

The duty cycle factor is merely a means of approximating the r. m. s. value of the duty cycle without resorting to the planimeter or to tedious graphical methods.

TABULATED DATA. Tables of values of the various factors entering into the probability formulas used are presented in an appendix, as well as tables for the computation of duty cycle factors.

NEW MATTER. It is believed that this paper presents for the first time an application of the theory of probabilities to the starting and stopping of motors. The theory of probabilities, or of statistics, has many possible applications in engineering which, of necessity, deals largely with statistical averages. The use of the theory in engineering has been strangely neglected.

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To be presented at the Annual Convention of the A. I. E. E., Niagara Falls, Ont., June 26-30, 1922.

Preliminary Note

ASSUMING a group of motors whose individual duty cycles are known, operating at random or nearly so, it is necessary to determine the resultant combined duty cycle in order to select the most suitable capacity of the conductors feeding the group, as well as the rating and type of the generating apparatus supplying the required energy, and of the protective apparatus. The average value and r. m. s. value of the resultant duty cycle are required, as well as the

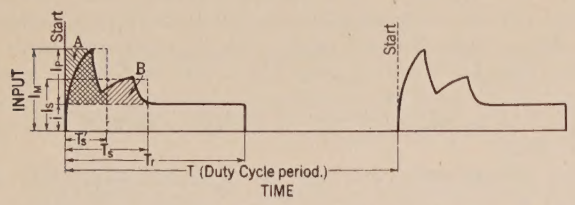


Fig. 1—Individual Duty Cycle
First Approximation.

maximum peaks, their duration and probable frequency of occurrence, together with some knowledge of the probable time distribution of the input. With such information available, even if it be only reasonably approximate, some intelligent selection of generating, distributing and protective equipment is possible. If the heat absorption and heat radiation constants of the current-carrying parts of the equipment are known, then the desirable rating of such parts on a basis of temperature rise may also be determined. Without such information the selection of equipment is largely a matter of guess work, more or less intelligent, depending upon experience and available records.

While the method proposed is worked out in detail for the case of a group of similar motors, all operating at random on the same duty cycle, it is obvious that, with suitable and not very serious complications, it can be applied to groups of dissimilar motors operating

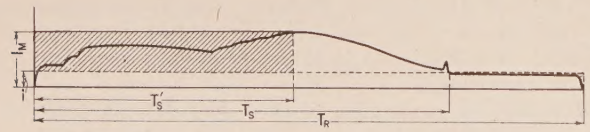


Fig. 2—Oscillogram
Direct-drive, 1 to 1 roping, traction-type elevator.

at random on different duty cycles, such as motors driving diversified machine tools. The method, as given, applies without change to traction systems.

The Individual Duty Cycle

The curve in Fig. 1 represents the average time distribution of the input to all of the individual motors in the group. The average time per cycle or between starts is T. The average time during the cycle when the motor is running is T_r. The average starting period is T_s. The average running input during the time T, omitting the starting peak, is i. The average input during the starting time is I_s. The average starting peak input above i is $I = I_s - i$.

If, in the resultant duty cycle of the group, the maximum value reached by the resultant peaks is of more importance than their duration, the value of I_s is to be changed to I_M, the maximum peak input; in which case $I_P = I_M - i$. As a first approximation, the duration of I_M is then taken at T_s^1 so that the area A between I_M and i is equal to the area B enclosed by the actual curve of peak input and i. Then in both cases, the product of input and time is the same. But, if the actual maximum input is of short duration, the resultant maximum peaks for the group found in this way will be too steep and of too long a duration.

For many cases, such as that shown in Fig. 2, this first approximation will be sufficient. This is an oscillograph of input to a direct-drive, 1 to 1 roping, traction-type elevator hoisting engine on resistance speed control. The error here introduced by considering the starting input to be constant and equal to the

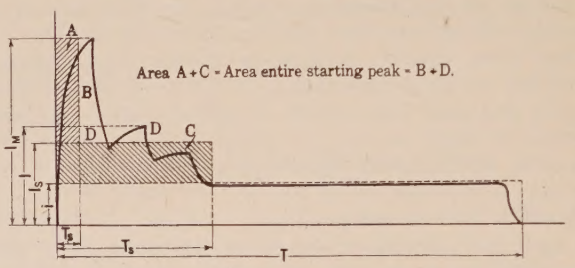


Fig. 3—Individual Duty Cycle
Second Approximation.

maximum input over a reduced starting period is negligible. But in cases like that shown in Fig. 3, a second approximation may be required. In this case the starting peak below I is averaged as I_s over the time T_s and the starting peak I_M above I is drawn of such duration, T_s^1, that the area A enclosed is equal to the area B of the actual peak above I. The total area is then the same as the actual peak area above i.

Obviously some judgment will be required in determining the approximation to be used. But without some such approximation the calculation of the resultant duty cycle becomes too cumbersome for practical use.

Another approximation has been introduced in considering the duty cycle used to be the average duty cycle for the group. If the group is divided into subgroups in each of which the motors are operating on very different average duty cycles, the calculations must be carried out for each sub-group separately and then combined. This difference may be in the time-distribution of the input during the duty cycle, in the duration of the duty cycle, or in both.

If the motors vary widely in capacity then a second sub-division into groups of motors of approximately the same capacity must be introduced and a separate calculation made for each such sub-group.

When the motors in the group number 20 or more in general no such sub-divisions of average duty cycles or capacities are necessary, unless a few relatively large motors may introduce a periodic large increase in the resultant input. In such special cases the particular motors must be treated as a sub-group.

In special cases it may be advisable to introduce approximations other than those above indicated. Again, if the starting peaks are not material or are relatively short, and particularly where, in such cases, the number of motors is large, it may be sufficient to average the entire input during the duty cycle, including the peak, and to omit from consideration the peaks above this average. If the peaks are of moment then at least two calculations are necessary, one for the average running input, i, and, depending on the order of approximation introduced, one or more for the peaks. The resultant duty cycles, one obtained by each such calculation, are then to be combined to obtain the over-all duty cycle. But in each case the method of calculation is the same, and, as will be seen from the case worked out below, is quite simple.

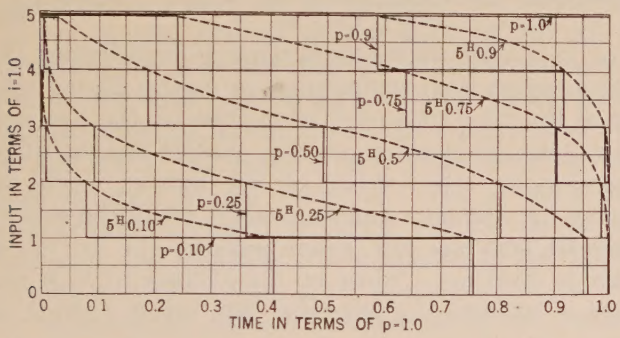


FIG. 3A—GROUP DUTY CYCLES
For $N = 5$, $i = 1.0$

METHOD OF CALCULATION

The method proposed is precisely the same as that used in determining the probable frequency of occurrence of any number of points in any number of throws of a given number of dice. As is well-known, this method very closely approximates to actual experience when the number of throws or trials is sufficiently large.

Let there be N motors in the group (or sub-group), the average duty cycle for which (Fig. 1) has the approximate values T, T_r, i, I_M, and let the duration of I_M be T_s[1]. Then, on the average, each motor is running a fraction of the time given as a decimal by

$$T_r/T = p \qquad (1)$$

This is also the average decimal of the total period considered, P, say 15 minutes or one hour as the case may be, during which any one motor in the group is running. If T and P be given in seconds, then P/T is the average number of duty cycles performed by each motor in the group in the time P. Since there are N motors in the group the total number of starts or runs made is

$$P/T \times N = R \qquad (2)$$

The number R corresponds to the number of trials or throws of the dice in the analogous dice problem.

Since, on the average, each motor is running a part of the time P denoted by p, the probability that any one particular motor is running at any particular time is p. But there are N motors in the group. So the relative frequency in the total number of trials or observations, R, that any one motor is running is $N\,p \times R$.

Since, on the average, each motor is running a part of the time P denoted by p, the probability that any motor is running at any particular time is p. The probability that it is standing still at any particular time is $(1 - p)$.

The probability that any particular two motors are running simultaneously at any particular time is p^2. Similarly the probability that any particular set of r motors are running simultaneously at any particular time is p^r. Since there are N motors in the group, the probability that they are all running simultaneously at any particular time is p^N.

The probability that any particular set of r motors are standing still simultaneously is $(1 - p)^r$. The probability that all of the N motors are standing still simultaneously is $(1 - p)^N$.

The probability that any particular set of r motors are running simultaneously, while the remaining $(N-r)$ motors are standing still simultaneously is $p^r \cdot (1 - p)^{N-r}$ But there are ${}^NC_r$ combinations of motors in the group taken either r or $(N - r)$ at a time, so the relative frequency with which the input due to r motors running simultaneously will occur, is

$$P_r = {}^NC_r \cdot p^r \cdot (1 - p)^{N-r} * \qquad (3)$$

It is not difficult to compute and tabulate, or chart, values of (3) over a useful range of N, r and p.

In general if $\{ (1 - p) + p \}^N$ be expanded as a binominal thus: $\{ (1 - p) + p \}^N = (1 - p)^N + N\,p\,(1 - p)^{N-1} + {}^NC_2\,p^2\,(1 - p)^{N-2} + \ldots + {}^NC_r\,p^r\,(1 - p)^{N-r} + \ldots + p^N$, (4)
the first term is the probability that all the N motors are standing still; the second term is the probability that one motor is running and $(N - 1)$ motors are standing still simultaneously; the third term is the probability that two motors are running simultaneously and $(N - 2)$ motors are standing still simultaneously; . . . . . ; the last term is the probability that all the N motors are running simultaneously. The sum of the terms in (4) is 1.0.

All of this is quite obvious, of course, to those who are familiar with the elements of the Theory of Probabilities.

Having determined the values of the terms in (4) as

* $\left({}^NC_r = \dfrac{N\,(N-1)\,(N-2)\,\ldots\,(N-r+1)}{r\,(r-1)\,(r-2)\,\ldots\,1} \cdot \right)$

P_0, P_1, P_2, . . . , P_r, . . . P_N, they may be taken respectively as the probability that the input to the group at any time may be that due to no motors running or zero input, that due to one motor running, that due to two motors running simultaneously, ..., that due to r motors running simultaneously, ... , that due to all the N motors running simultaneously.

To determine the probable time distribution of the resultant input proceed as follows:

There are R chances in the period P that the input will change (see (2) above). Of these chances the input will be probably that due to no motors running (zero load), $P_0 \times R$ times; the input will be probably that due to one motor running $P_1 \times R$ times; the input will be probably that due to two motors running simultaneously $P_2 \times R$ times; . . . . ; and the input will be probably that due to all the N motors running simultaneously $P_N \times R$ times.

Then, if $P = 1.0$ hour, chances are that $P_0 \times R = F_0$ times per hour the input will reach zero; the chances are that $P_1 \times R = F_1$ times per hour the input will be that due to one motor running; the chances are that $P_2 \times R = F_2$ times per hour the input will be that due to two motors running simultaneously; . . . . ; and the chances are that $P_N \times R = F_N$ times per hour the input will be that due to all the N motors running simultaneously. These results may be changed into time distribution by considering that n times per hour equals every $3600/n$ seconds.

Such calculations having been carried out for the running current, similar calculations are to be made for the starting peaks, repeated twice if two approximations have been introduced as explained above (see Individual Duty Cycle).

In the case of the starting peaks

$$T_s/T = p \text{ , and } T_s^1/T = p_s^1 \qquad (5)$$

giving the values of p for the two approximations both of which are different from the value of p found for the running current. The corresponding values of ${}^NC_r\, p_s^r\, (1 - p_s)^{N-r}$, and ${}^NC_r\, p_s^{1r}\, (1 - p_s^1)^{N-r}$ will be different from each other and different from the values of ${}^NC_r\, p^r\, (1 - p)^{N-r}$ found for the running input. In this case, the input per motor is $I_M - i = I_p$ if only one approximation is used (see Fig. 1). If two approximations are necessary the two values are $I_s - i$ for the first approximation, and $I_M - I_s$ for the second (see Fig. 3).

Average Input

The average input over the time P is found as follows; two calculations are necessary, one for the running input and one for the starting input.

First as to the running input:

Of the total time P, zero input exists for the time $P_0 \times P$; the input due to one motor running exists for the time $P_1 \times P$; the input due to two motors running simultaneously exists for the time $P_2 \times P$; . . . . ; and the input due to all N motors running simultaneously exists for the time $P_N \times P$. Each of these results is to be multiplied by their respective values of input o, i, $2\,i$, ... , $N\,i$, and the sum of the products taken. This sum, divided by P, is the average input. It is

$$\frac{(P_0 \times P \times 0) + (P_1 \times P \times i) + (P_2 \times P \times 2\,i) + \ldots + (P_N \times P \times N\,i)}{P}$$

$$= i(P_1 + 2\,P_2 + \ldots + N\,P_N) \qquad (6)$$

Similar calculations, using I_p instead of i in (6), must be carried out for the average starting input which is to be added to the average running input to get the total average input.

Simplified Method of Determining the Average Input

If $p\,T \times R$ or $T_r \times R$ is greater than P, so that on the average at least one motor is always running, the average running input A_r may be determined by

$$A_r = i\,N\,p \qquad (6a)$$

If $p_s\,T \times R$ or $T_s \times R$ is greater than P so that on the average at least one motor is always starting, the average starting input, A_s, may be determined by

$$A_s = I_p\,N\,p_s \qquad (6b)$$

For, if at least one motor is running (or starting) and each motor on the average runs (or starts) during that part of the time measured by p then on the average, $N\,p$ motors are running (or $N\,p_s$ motors are starting). Otherwise, in time, either all the motors would be running (or starting) simultaneously, or all the motors would be standing still simultaneously (or no motor would be starting). Since on the average at least one motor is running (or starting) the latter cannot be true.

When the motors all perform one average duty cycle, the determination of A_r or A_s by (6a) and (6b) respectively is simple. But when the duty cycles vary widely so that the ratings of the motors vary widely, these formulas, like (6), must be applied separately to each group of motors for which an average duty cycle may be taken. (See Average Duty Cycle above).

From the average input thus determined, the approximate power consumption in kilowatt-hours during the period P may be found; determinations of this kind have proved to be within 10 per cent of the actual yearly power consumption of groups of motors in service.

Root-Mean-Square-Input

As in finding the average input, separate calculations for the r. m. s. running input, and for the r. m. s. starting input are necessary.

The values of $P_0 \times P$, $P_1 \times P$, ... , and $P_N \times P$ are determined as above. Then each value is multiplied by the *square* of its respective input. The sum of these products divided by P is the mean-square input, and the square root of this is the root-mean-square input. It is

$$\left\{\frac{(P_0 \times P \times 0) + (P_1 \times P \times i^2) + (P_2 \times P \times 4i^2) + \ldots + (P_N \times P \times N^2 i^2)}{P}\right\}^{1/2} = i\,(P_1 + 4P_2 + 9P_3 + \ldots + N^2 P_N)^{1/2} \quad (7)$$

Similar calculations using I_p instead of i in (7), must be carried out for the r. m. s. value of the starting input, and added to the r. m. s. running input to get the total r. m. s. input.

Of course an error is introduced by treating a distributed series of equal load values as if the heating due to the distributed series were the same as a continuous load of the same amount, but lasting a single interval equal to the sum of the separate intervals. This error is not material for values of R equal to or greater than 1000. If R is much less than 1000 then it may be advisable to plot the actual load curve and determine temperature rise from the actual resultant duty cycle thus obtained.

The method assumes that the heating value of the distributed load as shown by curve T in Fig. 5, is the same as the heating value of the curve H shown in this same figure. Curve H is obtained by assembling together in one interval, as expressed by (6), all the separate input intervals that fall within a given range of input for both running and starting. Thus all the separate intervals during which the input lies between 200 and 300 in the curve T have been assembled as a single interval in the curve H. The actual r. m. s. value of both curves is the same, but due to the heat absorption and radiation characteristics of the current-carrying devices or equipment, in general the momentary temperature rise will be different for the assumed duty cycle H and the actual duty cycle T. Generally this difference will be in favor of the actual duty cycle. For instance, a fuse that would blow if subjected to the duty cycle H, would not blow if subjected to the duty cycle T. A fuse subjected successfully to a current of 600 amperes for a second or two at comparatively long intervals would blow if subjected to this same current for 7.2 seconds continuously.

The curve H may be considered as the characteristic frequency curve of input distribution in the particular case for which it has been determined. If curve-drawing instrument charts, giving time distribution of input to any group of motors, is available, the H curve may be determined graphically from the observed input distribution, exactly as it is determined above from the calculated input distribution.

For various values of N and p taking i as 1.0, characteristic H curves may be computed and graphed for comparison with H curves determined by observation. A selection of the appropriate standard H curve for any observed value of N determines the approximate over-all value of p for the group of motors under observation.

Such standard group duty cycles for $N = 5$ and various values of p are shown in Fig. 3A. These curves assume $p_s = 0$, or that the starting peaks are of no material moment. These curves are determined for $P = 1.0$ and $i = 1$.

Method of Plotting Time Distribution of Input

The various possible probable values of input as calculated above, namely, that due to one motor running, that due to two motors running simultaneously, ... , and that due to N motors running simultaneously, may then be spotted on a cross-section sheet taking one border as time and the other as input. These points establish the probable beginning of each change in input. The input remains constant till the next change occurs.

This square topped input curve may then be converted into a curve more resembling an actual curve-drawing instrument record by plotting the resultant input values at equal time intervals, say every two seconds, or five seconds, and by drawing straight lines between these points. If there are two groups or more for which the same calculations have been made, then the resultant input curves should be drawn on the same sheet for each group and their separate values at equal time intervals added to obtain points on the total curve.

A similar, and separate curve is then to be plotted for the peak input, and added to the running curve.

Such curves, plotted from computed probable values of input, may be compared properly with actual curve-drawing instrument records of input only with the understanding in mind that the computed value of the input at any time during the resultant cycle is the most probable value at that time. It should be compared only with the average of the values of the actual input at the same or corresponding intervals. In other words, the form of the computed curve of time distribution of input is the most probable form of the actual record curve.

Frequency of Combined Running and Starting Inputs

Having determined, as explained above, the probable frequencies $P_0, P_1, P_2, \ldots$ etc. for both running and starting inputs, the frequency with which any combination of running and starting inputs will probably occur can be determined by multiplying together their separate frequencies. Thus, to determine the probable frequency with which the input due to r motors running simultaneously, and the input due to q motors starting simultaneously will occur at the same time, the value of P_r for the running input, and the value of $P\,q$ for the starting input are to be multiplied to get P_{qr}. This may then be converted into terms of "times per hour."

Applications

The method outlined has been applied to actual installations of motors where the calculated results could be checked by comparison with records from curve-drawing and integrating instruments. The com-

puted values always compare very favorably with the actual operating averages. In this, there is nothing strange, for the method of probabilities always leads to results that closely correspond to experience, and experience consists of just such statistical averages.

Example. Consider the case for which $N = 6$, $T = 20$ sec., $T_r = 10$ sec., $P = 3600$ sec., $i = 100$, and, to the first approximation, let $I_M = 200$, for $T_s^1 = 5$ sec. Then $p = 10/20 = 0.5$; $p_s = 5/20 = 0.25$; $R = 3600/20 \times 6 = 1080$.

The first step in the calculation is to determine values of ${}^NC_r\, p^r\, (1-p)^{N-r} = P_r$ for $p = 0.5$. They are

1. $P_0 = (1-p)^N = 0.5^6 = 0.015625 = 0.0156$ nearly
   $P_1 = {}^6C_1 \times 0.5 \times 0.5^5 = 0.093750 = 0.0938$ "
   $P_2 = {}^6C_2 \times 0.5^2 \times 0.5^4 = 0.234375 = 0.2344$ "
   $P_3 = {}^6C_3 \times 0.5^3 \times 0.5^3 = 0.312500 = 0.3125$ "
   $P_4 = {}^6C_4 \times 0.5^4 \times 0.5^2 = 0.234375 = 0.2344$ "
   $P_5 = {}^6C_5 \times 0.5^5 \times 0.5 = 0.093750 = 0.0938$ "
   $P_6 = {}^6C_6 \times 0.5^6 = 0.015625 = 0.0156$ "

   1.000000

These values of P_0, P_1, P_2, etc. have been plotted in Fig. 4. It will be seen that because $p = 0.5 = (1-p)$ the resulting curve is symmetrical with respect to the maximum value of P_3. The most probable running

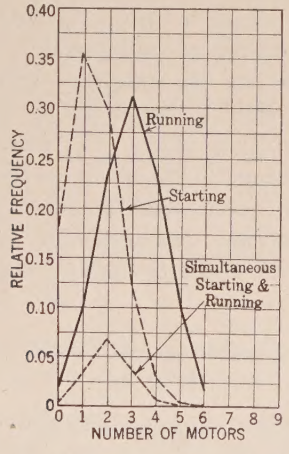


FIG. 4—FREQUENCY CURVES FOR SIX MOTORS
$p = 0.5$, $p_s = 0.25$

input is that due to three motors running simultaneously. In this case it is also the average input.

The next step is to determine values of $P_r \times R = F_r$. They are

2. $F_0 = 0.0156 \times 1080 = 16.85$ times
   $F_1 = 0.0938 \times 1080 = 101.30$ "
   $F_2 = 0.2344 \times 1080 = 253.05$ "
   $F_3 = 0.3125 \times 1080 = 337.50$ "
   $F_4 = 0.2344 \times 1080 = 253.05$ "
   $F_5 = 0.0938 \times 1080 = 101.30$ "
   $F_6 = 0.0156 \times 1080 = 16.85$ "

Now the trials, $R = 1080$ occur in 3600 seconds or 1 hour, so from (2);

3. 16.85 times per hour is equivalent to every 213.6 sec.
   101.30 " " " " " " " 35.5 "
   253.05 " " " " " " " 14.2 "
   337.50 " " " " " " " 10.7 "
   253.05 " " " " " " " 14.2 "
   101.30 " " " " " " " 35.5 "
   16.85 " " " " " " " 213.6 "

Therefore the running input will probably reach that due to no motors running or zero input, every 213.6 sec.; it will probably reach that due to one motor running, or 100 amperes every 35.5 sec.; it will probably reach that due to two motors running simultaneously, or 200 amperes every 14.2 sec.; . . . . ; it will probably reach that due to all six motors running simultaneously, or 600 amperes every 213.6 sec.

It is to be noted that zero input and that due to all the six motors running simultaneously occur with the same frequency. This is also true of the input due to two motors running simultaneously, and the input due to four motors running simultaneously. In such cases either one or the other input is equally likely to occur.

The average running input by (**6**) is

$$100\,(0.0938 + 2 \times 0.2344 + 3 \times 0.3125 + \ldots + 6 \times 0.0156) = 300 \text{ amperes.}$$

Note that by (**6a**), $A_R = 100 \times 3 = 300$.

The root-mean-square running input, by (**7**), is

$$100\,(0.0938 + 4 \times 0.2344 + 9 \times 0.3125 + \ldots + 36 \times 0.0156)^{1/2} = 324 \text{ amperes.}$$

Similar calculations must now be made for the starting peak input. Here $p_s = 0.25$, so the values of ${}^NC_r\, p_s^r\, (1-p_s)^{N-r}$ are

4. $P_0 = (1-p_s)^6 = 0.75^6 = 0.1780$
   $P_1 = {}^6C_1 \times 0.25 \times 0.75^5 = 0.3564$
   $P_2 = {}^6C_2 \times 0.25^2 \times 0.75^4 = 0.2966$
   $P_3 = {}^6C_3 \times 0.25^3 \times 0.75^3 = 0.1234$
   $P_4 = {}^6C_4 \times 0.25^4 \times 0.75^2 = 0.0308$
   $P_5 = {}^6C_5 \times 0.25^5 \times 0.75 = 0.00411$
   $P_6 = {}^6C_6 \times 0.25^6 = 0.002285$

These results have also been plotted in Fig. 4. The resulting curve is unsymmetrical (skew) with respect to the most probable value, P_1. The most probable starting input is that due to one motor starting.

The next step is, as before for the running inputs,

2. $F_0 = 0.1780 \times 1080 = 192.24$ times
   $F_1 = 0.3564 \times 1080 = 384.91$ "
   $F_2 = 0.2966 \times 1080 = 320.33$ "
   $F_3 = 0.1234 \times 1080 = 133.27$ "
   $F_4 = 0.0308 \times 1080 = 33.26$ "
   $F_5 = 0.00411 \times 1080 = 4.44$ "
   $F_6 = 0.00229 \times 1080 = 1.57$ "

Then,

3. 192.24 times per hour is equivalent to every 18.7 sec.
   384.91 " " " " " " " 9.4 "
   320.33 " " " " " " " 11.2 "
   133.27 " " " " " " " 28.1 "
   33.26 " " " " " " " 108.2 "
   4.44 " " " " " " " 812.0 "
   1.57 " " " " " " " 2300.0 "

Therefore the starting input will probably reach zero every 18.7 sec.; it will probably reach that due to one motor starting every 9.4 sec.; it will probably reach that due to two motors starting simultaneously every 11.2 sec.; . . . . . ; it will probably reach that due to all six motors starting simultaneously every 2300 seconds.

The average starting input, by (**6**) is

$$100\,(0.356 + 2 \times 0.297 + 3 \times 0.123 + \ldots + 6 \times 0.0023) = 148 \text{ amperes}$$

Note that by (**6b**), $A_R = 100 \times 1.5 = 150$.

This is to be added to the average running input of 300 amperes to get the total average. It is 448 amperes.

The root-mean-square starting input, by (**7**), is

$$100\,(0.356 + 4 \times 0.297 + 9 \times 0.123 + \ldots + 36 \times 0.0023)^{1/2} = 183 \text{ amperes.}$$

which is to be added to the r. m. s. running input of 324 amperes to get the total r. m. s. It is 507 amperes.

The kilowatt-hours consumed by the motors in any period during which these conditions hold can be determined from the total average input. It will be found to check very closely with the power consumption of the actual motors in actual service as measured by a watt-hour meter. The conductors feeding the group should be selected on the basis of the total r. m. s. input. The average drop in these conductors will be a function of the total average input.

The periodicity of peaks for this case may be worked out as follows:

The heaviest possible running input of 600 amperes due to six motors running simultaneously occurs every 213.6 seconds, the corresponding value of P_6 is 0.0156. Starting peaks may be added to this. Four motors start simultaneously every 108.2 sec. The corresponding value of P_4 is 0.0308. The probability that both will occur together is the product $0.0156 \times 0.0308 = 0.0048$. This has a probable frequency of $0.0048 \times 1080 = 5.18$ times per hour, or every 695 seconds; which is equivalent to once every 11.6 minutes. Its duration will be less than $T_s{}^1 = 5$ sec.

For six motors running and five motors starting simultaneously, the probable frequency is $0.0156 \times 0.0041 = 0.000064$. This is equivalent to 0.069 times per hour, or once every 52174 sec.; which is equivalent to once every 14 hours and 30 minutes. The corresponding input is 1100 amperes. It is probable that for most purposes this peak can be neglected.

The time distribution of input for this case is shown in Fig. 5. The curve R is the running input. The curve S is the starting input. The curve T is the total input. Greater peaks will appear if the curve is extended, due to the combination of running and starting peaks.

The method of plotting may be illustrated by the curve R. Referring to column *3* in the calculations for running input, it is found that zero input occurs every 213.6 sec. and that the input due to one motor running or 100 amperes occurs every 35.5 sec. The corresponding points *b, b, b,* . . . are plotted. Then the load of 200 amperes due to two motors running simultaneously is plotted every 14.2 sec. . . . Since the input every 35.5 sec. is equally likely to be either 100 or 300 amperes, the two values have

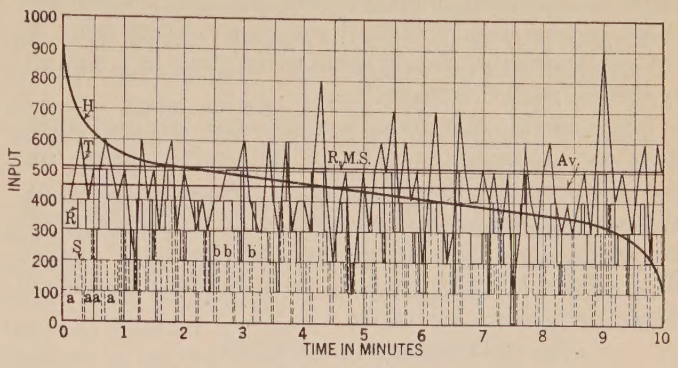


FIG. 5—TIME DISTRIBUTION OF INPUT
$N = 6$, $T = 20$ sec., $T_r = 10$ sec., $T_s = 5$ sec.
$p = 0.5$, $p_s = 0.25$, $i = 100$, $I_p = 100$.
Curve T plotted in 6-sec. intervals.

been plotted alternately. The same is true of the input every 14.2 sec. which is equally likely to be either 200 amperes or 400 amperes.

As explained above (Method of Plotting Time Distribution of Load), the square topped curve R is drawn through these points.

The starting input curve S is plotted and drawn in a similar manner.

Then, at every 6.0-sec. interval ordinates have been drawn and the sum of the input values given by the intercepts of these ordinates with the R and S curves, laid off as the corresponding ordinates of the curve T.

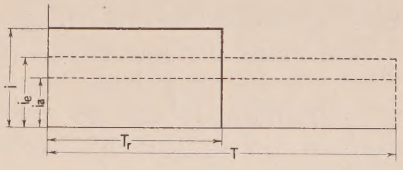


FIG. 6—CONSTANT-CURRENT DUTY CYCLE

DEMAND FACTOR

From the above discussion it will be seen that unless a statement of so called "demand factor" is coupled with a statement of frequency and duration, it means nothing and is more likely to be misleading than helpful.

In the above case, if the motors are rated for temperature rise, as they should be, by the r. m. s. input per motor, their rated input will be 84.5. If they are rated by the average input per motor their rated input will be 74.6, nearly 10 less, and equivalent to a continuous overload of over 13 per cent, involving an increase in temperature of about 23 per cent.

Commonly they will be rated by guess work and will be about twice too big for their work, involving increased annual charges and reduced efficiency.

If the motors are rated at 84.5, their united input

is 507. A demand equal to 507 will probably occur at least every 15 minutes, for which the demand factor is 1.0. But the duration of this demand will be only a few seconds at most.

If the motors are rated by guess work this demand factor may drop to about 0.5 which is not an uncommon value to find with values of p approximating 0.5. A low demand factor should mean a low value of p, not an excessive motor installation.

The probable maximum demand over any period of time, say 15 minutes, may be determined from the curve of time distribution of input. A mere statement of such demand, unless coupled with a statement of frequency, does not determine the character of the input, and is not a logical basis for the determination of rates.

Temperature Rating

Consider the individual duty cycle shown in Fig. 6. The input i is constant for the time $T_r = p\,T$. The

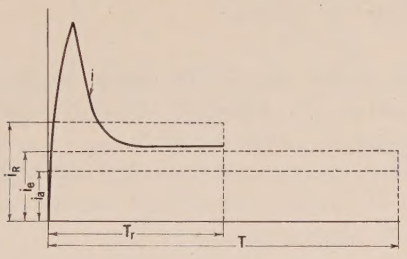


Fig. 7—Variable-Current Duty Cycle

equivalent average input for the time T is i_a. The heat liberated by the current i for the time $p\,T$ is $H_i = C\,W\,i^2\,p\,T$, where C is a constant and W the resistance of the circuit. Similarly, the heat liberated by the current i_a flowing for the time T is $H_a = C\,W\,i_a^2\,T$. The ratio of these is

$$H_i/H_a = \frac{i^2\,p}{i_a^2}\,.$$

But $i_a = p\,i$. Therefore $H_i/H_a = 1/p$.

Obviously more heat is liberated by the current i flowing for the time $p\,T$ than is liberated by the equivalent average current i_a flowing for the longer time T. The smaller is p the greater is this difference.

Assume that it is desired to determine the value of the current flowing for the time T that will liberate the same amount of heat as the current i flowing for the time $p\,T$. Let this desired current be i_e. Then $i^2\,p\,T = i_e^2\,T$, or $i^2/i_e^2 = i/p$. Therefore $i/i_e = (1/p)^{1/2}$

If, as in Fig. 7, the current i is not reasonably constant during the time $p\,T$, find its r. m. s. value i_R. Then $i_R/i_e = (1/p)^{1/2}$.

This is the basis on which conductor temperature rating may be established.

If the current i_e flows in indefinitely, the conductor will reach maximum temperature t_e in the time P_t depending on its radiation constant, etc. If in any case, conductors or fuses, the value of T should be greater than P_t, while $p\,T$ is less than P_t, then a new value of p must be found. It is $p_t = p\,T/P_t$. Then, for equal heat generation, the basis for rating is $i_r/i_{et} = (1/p_t)^{1/2}$, where i_{et} is the equivalent constant current for the time P_t. If $p\,T$ is longer than P_t then i_r is the same as the equivalent constant current. This would be the case for the distribution curve T in Fig. 5. Here the duty cycle period is taken at 15 min. But the input does not reach zero, so the r. m. s. value of input is the required equivalent constant-current rating. Otherwise than as pointed out above, the value of T does not enter into the formulas. It does not matter whether $p\,T$ be 5 seconds, 10 minutes or longer, provided T does not exceed P_t.

When, as in nearly all actual duty cycles, the starting peak is too pronounced to permit figuring it in as a slight increase in i during the time $p\,T$, the heat liberated by the peak must be computed separately. If the r. m. s. of the peak, in addition to the average running current i_a, is I_{pr} for the time $p_s\,T$, where, as above, $p_s = T_s/T$, then the equivalent constant current for the time T is $I_e = p_s^{1/2}\,I_{pr}$. The total equivalent constant current is then $I_{et} = i_e + I_e = i\,p^{1/2} + p_s^{1/2}\,I_{pr}$ (or if necessary, i_R may be used instead of i). The value of I_{pr} may be given in terms of i (or i_R) as $I_{pr} = c\,i$. Then $I_{et} = i\,(p^{1/2} + c\,p_s^{1/2})$. It is proposed to call the term $(p^{1/2} + c\,p_s^{1/2})$ the "duty cycle factor," and write it d. That is $I_{et} = i\,d$, or $i = I_{et}/d$. By taking I_{et} to be the rated constant current given in the N. E. C. Table I in Rule 18-b, then, by giving various values to d the appropriate rating of all such conductors can be determined for the corresponding duty cycles for which the actual running current is i, and the duty cycle factor is d.

It is assumed that in no case does T exceed P_t, or the time required to bring any conductor to its maximum allowable temperature with rated constant current flowing. If T is longer than P_t, new values of p and p_s must be found. If T_r is longer than P_t, then i or i_r is the equivalent running current, but a new value p_{st} must be found for p_s. The duty cycle factor then becomes $d = (1 - c\,p_{st}^{1/2})$.

We may then write down such conductor ratings, giving quite arbitrary values to d. The following table gives the corresponding ratings for a few rubber-covered conductors in conduit.

TABLE I

Size	N. E. C. Rating $d = 1.0$	Ratings for valus of d			
		$d = 0.866$	$d = 0.706$	$d = 0.50$	$d = 0.25$
No. 14	15	17	20	30	60
No. 12	20	23	26	40	80
No. 10	25	29	33	50	100
No. 8	35	40	46	70	140
No. 6	50	57	66	100	200
No. 4	70	80	92	140	280
No. 2	90	100	110	180	360
2/0	150	172	197	300	600
4/0	225	258	300	450	900
0.3/0″	275	316	362	550	1100
0.6/0″	450	518	592	900	1800

It is of interest to check these results with time ratings arrived at by test. Assume that $P_t = 30$ minutes. This is a safe assumption particularly for the larger sizes. Assume a duty cycle such as shown in Fig. 6 and let T be equal to P_t. For this duty cycle I_{pr} and p_s vanish, and $d = p^{1/2}$. The time ratings will be given by $i_{et} = i/p^{1/2}$ where i is the N. E. C. rating. The value of p is given by T_r/P_t.

The calculated results marked "Cal." are given below for various values of T_r, together with test results marked "Rep." taken from the Report of the Committee on Demand Factor Western Association of Electrical Inspectors, dated Aug. 20, 1920.

TABLE II

Size	N. E. C. Rating d = 1.0	Ratings for values of T_r in minutes							
		Cal. 22.5 min.	Rep. 30.10 min.	Cal. 15 min.	Rep. 15 min.	Cal. 10 min.	Rep. 10 min.	Cal. 5 min.	Rep. 5 min.
14	15	17	19	20	22	26	24	36	30
12	20	23	24	25	26	33	29	49	35
10	25	29	30	33	35	43	40	61	45
8	35	40	43	46	50	61	60	85	65
6	50	57	60	66	73	85	80	121	105
4	70	80	77	92	97	120	110	170	140
2	90	100	106	110	130	156	155	210	195
2/0	150	172	179	197	220	264	260	365	340
4/0	225	258	256	300	325	389	395	550	515
0.3/0″	275	316	345	362	435	475	536	670	690
0.6/0″	450	518	610	592	750	780	915	1100	1225

The average deviation of the calculated results from the test results in the columns for 15 min., 10 min. and 5 min. respectively are − 29 amperes, + 9 amperes and + 2 amperes. The over-all agreement is remarkably close. Lack of knowledge of the method and refinement of the test referred to in the report mentioned, makes it impossible to compare individual results.

It is evident that the assumption $P_t = 30$ min. is somewhat low and probably too general. If P_t is increased the calculated results for the same values of T_r will be reduced.

It will be seen that if the rated continuous current and the value of P_t for any current-carrying device is given, the proper rating of the device for any other duty cycle for which d is known may be easily determined.

The duty cycle factor may be applied to a motor, thus: If the motor be name-plate rated at A amperes for M minutes, then M is the value of P_t for the motor. Let T, T_r, T_s, i_r and I_{pr} be determined for the duty cycle on which the motor is to operate. Then if T is no longer than P_t, the values of p and p_s may be taken from the duty cycle, and the duty cycle factor d determined. Then if A is no less than i_r/d, the given motor will carry the imposed duty for the time P_t without exceeding its rated temperature. If the duty cycle only is given then $A = i_r/d$ is the required rating for the time P_t of the proper motor for this duty. In general P_t will be taken as the time during which the duty will be imposed and may include a number of successive duty cycles.

If the value of P_t for a given type of motor is determined, the motor will carry the imposed duty cycle for a time P longer than P_t if $A = i_r/d \times P_t/P$ is the motor rating for the time P_t.

The R. M. S. Rating of Fuses

All that has been said above is equally true of the rating of fuses. Thus a fuse rated at 100 amperes constant current will also properly serve to protect a properly rated motor, for which $d = 0.25$ and $I_{et} = 200$ amperes. A larger fuse than this will not properly protect the motor against overheating. Therefore in selecting the proper fuse protection of a motor it is necessary to know not only its rating, but also its probable duty cycle of input and the corresponding value of d. Of course P_t will be different for fuses and for conductors in conduit. It will be different for conductors in conduit and for exposed conductors.

In cases where T is relatively long, it will be found that usually the starting peak has little effect in determining the value of I_{et} and can be neglected. If therefore, the rating of fuses, as now required by the Underwriters' rules, is based rather on the average value of starting peak than upon the value of I_{et} or total equivalent constant current, a fuse will be selected that will not protect the motor against undue temperature rise due to prolonged overloads. Numerous cases of such failure of fuse protection have been noted.

Consider the case in which $p = T_r/T = 0.64$ and $p_s = T_s/T = 0.16$. Determine the average running current i during the time T_r. Assume it to be nearly constant during the time $T_r - T_s$ so its r. m. s. value i_r may be taken equal to i. The equivalent constant current value for the time T is $i_e = p^{1/2} i = 0.8\, i$, on which basis a fuse may be selected for the running current only.

Now determine the r. m. s. value of the starting input I_{pr} above i over the time T_s. Its equivalent constant current over the time T is $I_e = p_s^{1/2} I_{pr} = 0.4\, I_{pr}$. Assume that $I_{pr} = 2.0\, i$ (or $I_{pr} = 2.0\, i_R$ if the running input during the time $T_r - T_s$ had been irregular enough to require that i_R be used instead of i). Then $I_e = 0.8\, i$ and the total equivalent constant current I_{et} is $1.6\, i$. Obviously the fuse to be selected would have little if any value during the running period as a protection to the motor against overloads up to 160 per cent of load.

Yet, if a smaller fuse be selected it will not carry the motor over its duty cycle. There are three possible solutions of this difficulty. 1. Let the motor start one set of fuses and run on another set of different rating. Quite generally the proper capacity of the running fuses will be larger than the proper capacity of the starting fuses. 2. Instead of the fuses, use a circuit breaker set to come out only if an excessive overload lasts for a period sufficiently long to overheat the motor. This may be accomplished by the use of time limit relays. The third, and usual, solution is to

use an oversized or underrated motor, capable of standing overloads for sufficient time to bring to rupturing temperature the fuse of the capacity required to carry over the total duty cycle.

The following table gives the equivalent constant current rating of fuses in terms of the average (or r. m. s.) running input i, for various values of the root-mean-square of the starting peak I_{pr} expressed in terms of i as overload, and for various values of P_{st}. It is assumed that T, or the running time of the motor, exceeds P_t, or the time it takes the fuse, rated at i amperes, to reach maximum rated temperature. In other words, so far as the fuse is concerned, after start the motor runs continuously. The rating formula then becomes $I_{et} = i + p_{st}^{1/2} I_{pr}$ or $I_{et} = i + p_{st}^{1/2} c\, i$ where $c\, i = I_{pr}$. Then $I_{et} = i\,(1 + c\, p_{st}^{1/2})$.

TABLE III

p_{st}	Values of $I_{pr} = c\, i$ (overload during start)					
	0.25 i	0.50 i	0.75 i	1.00 i	1.25 i	1.50 i
0.10	1.08 i	1.16 i	1.24 i	1.32 i	1.39 i	1.48 i
0.20	1.11 i	1.22 i	1.34 i	1.45 i	1.56 i	1.67 i
0.30	1.14 i	1.27 i	1.41 i	1.58 i	1.69 i	1.82 i
0.40	1.16 i	1.32 i	1.47 i	1.63 i	1.79 i	1.95 i
0.50	1.18 i	1.35 i	1.53 i	1.71 i	1.89 i	2.06 i
0.60	1.19 i	1.39 i	1.58 i	1.77 i		
0.70	1.21 i	1.42 i	1.63 i			
0.80	1.22 i	1.45 i				
0.90	1.23 i	1.47 i				
1.00	1.250 i	1.50 i				

Thus, if the r. m. s. starting peak of any motor is 25 per cent overload (in terms of the actual constant running current i) that is, if $I_{pr} = c\, i = 0.25\, i$, and if the duration of this peak, T_s, is $p_{st} = 0.70$ of P_t, then a fuse must be used whose equivalent constant-current rating is 1.21 i. That is to say the motor may run continuously at 21 per cent overload (in terms of i) without exceeding the required fuse rating.

The Underwriters' rules permit the marked rating of a fuse to be 80 per cent of its equivalent constant-current rating. In other words the fuse will carry 25 per cent over its marked rating indefinitely. Such equivalent ratings are included above the upper dotted line in the table. A fuse whose marked rating is i will serve in all such cases. It is also understood that approved fuses shall blow instantly at 50 per cent overload. Equivalent ratings less than this are included above the lower dotted line. Thus, for $I_{pr} = 0.75i$ (75 per cent motor overload during start) and $p_{st} = 0.40$ or $T_s = 0.4\, P_t$, a fuse rating must be used that will permit a continuous running overload of 47 per cent. A fuse rated at less than this will not permit the motor to start and run for the time P_t. If, on the other hand, the motor can operate successfully at a continuous reasonable overload, a larger fuse must be selected provided it is concluded that the motor may start and carry this overload for any material part of the time P_t

Assume this overload is 0.10 i, then the formula becomes $I_{et} = 1.1\, i + p_{st}^{1/2} I_{pr}$. For $p_{st} = 0.70$, and $I_{pr} = 0.55\, i$, the value of I_{et} is found to be 1.56 i. In other words, the fuse will permit the motor to run at 56 per cent overload. In general the r. m. s. value of the starting peak will also increase under such conditions, requiring a fuse still larger than this.

It is probable that for all conditions contained between the broken lines in the table double fuse arrangements should be used; either this or circuit breakers with time limit relays, the latter being always used for cases below the second dotted line.

As an example, consider an induction motor driving a pump. Assume that the running input after the water is in motion at normal velocity is 100 amperes per phase at 80 per cent power factor, therefore, the heating value of the input must be based on $i = 125$ amperes per phase. Let the motor be started by a compensator, or step reactance, so that the r. m. s. starting input will be 250 amperes at an average power factor of 60 per cent. The heating value of this input must be based on 425 amperes. Then, $I_{pr} = 425 - 125 = 300$ amperes. Therefore $I_{pr} = 300\ 125 = 2.4\, i$, (a value not given in the table). Assume that the duration of the starting period T_s, is 5 seconds. Assume $P_t = 15$ sec. Then $p_{st} = T_s/P_t = 0.33$, and $p_{st}^{1/2} = 0.57$.

The resulting value of $I_{et} = i + p_{st}^{1/2} I_{pr}$, is $125 + 0.57 \times 2.4 \times 125 = 296$ amperes. Therefore a fuse whose actual rating at $P_t = 15$ sec. is 300 amperes, will serve to start the motor and run it, but will also permit 300 amperes, or more than double full-load running input, to flow continuously. If a fused marked at 300 amperes for the same value of P_t were used it would pass 375 amperes continuously. A fuse marked 250 amperes will pass 300 amperes continuously and is probably the best rating to use, if a single set of fuses is required. As a matter of protecting the motor against prolonged over loads, one set of starting fuses rated at $0.57 \times 2.4 \times 125 = 171$ amperes may be used. Actually a fuse marked 150 amperes would serve. For the running side, a fuse marked 125 amperes would be the nearest safe size. Of course, if the name-plate continuous duty rating of the motor exceeds 100 amperes at 80 per cent power factor, larger fuses can be used with safety on both starting and running sides, remembering that since the motor will be operating at fractional load, the power factor during both start and run, under the actual duty conditions, will be lower than those given. If P_t is greater or less than the assumed value of 15 seconds, the value of I_{et} will be altered correspondingly.

TABLE IV—1.
Values of p^r and $(1-p)^{N-r}$

r or $(N-r)$	p	$(1-p)$	p	$(1-p)$	p	$(1-p)$	p	$(1-p)$	p	$(1-p)$
	$(1-p)$	p	$(1-p)$	p	$(1-p)$	p	$(1-p)$	p	$(1-p)$	p
1	0.05	0.95	0.10	0.90	0.15	0.85	0.20	0.80	0.25	0.75
2	0.25×10^{-2}	0.903	0.010	0.810	0.0225	0.723	0.040	0.640	0.0625	0.562
3	0.125×10^{-3}	0.807	0.1×10^{-2}	0.729	0.338×10^{-2}	0.614	0.8×10^{-2}	0.510	0.0156	0.422
4	0.625×10^{-5}	0.815	0.1×10^{-3}	0.656	0.506×10^{-3}	0.522	0.160×10^{-2}	0.410	0.391×10^{-2}	0.316
5	0.313×10^{-6}	0.774	0.1×10^{-4}	0.591	0.759×10^{-4}	0.444	0.320×10^{-3}	0.328	0.976×10^{-3}	0.247
6	0.156×10^{-7}	0.746	0.1×10^{-5}	0.531	0.114×10^{-4}	0.377	0.640×10^{-4}	0.262	0.244×10^{-3}	0.178
7	0.781×10^{-9}	0.698	0.1×10^{-6}	0.478	0.170×10^{-5}	0.320	0.138×10^{-4}	0.210	0.610×10^{-4}	0.133
8	0.391×10^{-10}	0.664	0.1×10^{-7}	0.431	0.263×10^{-6}	0.273	0.256×10^{-5}	0.168	0.152×10^{-4}	0.100
9	0.196×10^{-11}	0.631	0.1×10^{-8}	0.387	0.385×10^{-7}	0.232	0.512×10^{-6}	0.134	0.381×10^{-5}	0.0750
10	0.976×10^{-13}	0.599	0.1×10^{-9}	0.348	0.577×10^{-8}	0.197	0.105×10^{-6}	0.107	0.954×10^{-6}	0.0562
11	0.488×10^{-14}	0.568	0.1×10^{-10}	0.314	0.866×10^{-9}	0.167	0.205×10^{-7}	0.0859	0.237×10^{-6}	0.0422
12	0.245×10^{-15}	0.540	0.1×10^{-11}	0.282	0.130×10^{-9}	0.142	0.412×10^{-8}	0.0687	0.596×10^{-7}	0.0322
13	0.122×10^{-16}	0.513	0.1×10^{-12}	0.254	0.195×10^{-10}	0.121	0.825×10^{-9}	0.0595	0.149×10^{-7}	0.0237
14	0.612×10^{-18}	0.487	0.1×10^{-13}	0.229	0.294×10^{-11}	0.103	0.164×10^{-9}	0.0440	0.373×10^{-8}	0.0178
15	0.311×10^{-19}	0.466	0.1×10^{-14}	0.206	0.437×10^{-12}	0.0876	0.328×10^{-10}	0.0352	0.932×10^{-9}	0.0133
16	0.153×10^{-20}	0.440	0.1×10^{-15}	0.185	0.657×10^{-13}	0.0744	0.656×10^{-11}	0.0281	0.233×10^{-9}	0.0100
17	0.756×10^{-22}	0.418	0.1×10^{-16}	0.167	0.986×10^{-14}	0.0658	0.131×10^{-11}	0.0225	0.583×10^{-9}	0.750×10^{-2}
18	0.382×10^{-23}	0.397	0.1×10^{-17}	0.150	0.148×10^{-14}	0.0475	0.262×10^{-12}	0.0180	0.146×10^{-10}	0.562×10^{-2}
19	0.191×10^{-24}	0.377	0.1×10^{-18}	0.145	0.224×10^{-15}	0.0406	0.525×10^{-13}	0.0144	0.364×10^{-11}	0.422×10^{-2}
20	0.956×10^{-26}	0.368	0.1×10^{-19}	0.131	0.322×10^{-16}	0.0343	0.105×10^{-14}	0.0116	0.811×10^{-12}	0.322×10^{-2}

All of this assumes that the name-plate rating of a motor means what it says, which generally is not the case.

The Operating Factor p

The factor p is here designated as the *operating factor* because it determines that part of the time the motor is actually operating. Similarly $(1-p)$ determines that part of the time the motor is standing still. It is "dead time" when the driven machine is producing nothing. The higher the value of p, the more nearly continuous is the machine operation, the more the machine produces per day, and the less the overhead charges per unit of work accomplished. Every live factory manager spends much of his time in efforts to increase the value of p in his shop. By working the above method of computing resultant duty cycles backward, he can determine the existing average value of p from a curve-drawing instrument chart of input to his shop.

Let us say that $(1-p)$ is a measure of the time when work is being removed from tools and being replaced. It is therefore a measure of man-power hours, just as p is a measure of horse-power hours. Roughly speaking, $p = 0.5$ means that half the time is spent in manual work.

Also the higher the value of p the more nearly constant is the load on the generating plant. Its efficiency is thereby increased. Fewer interruptions due to momentary excessive overloads will occur. The distributing system costs less per kilowatt-hour transmitted.

Appendix

The accompanying tables, giving values of p^r, $(1-p)^{N-r}$ (Tables IV-1 and IV-2), and ${}^{N}C_r$ for values of N up to 20, (Tables V-1 and V-2), will be useful in applying (**4**), (**6**), and (**7**) from *Method of Calculation.*

For values of N greater than 20 the calculations of resultant duty cycles by the method given above

TABLE IV—2.
Values of p^r and $(1-p)^{N-r}$

r or $(N-r)$	p	$(1-p)$	p	$(1-p)$	p	$(1-p)$	p	$(1-p)$	p
	$(1-p)$	p	$(1-p)$	p	$(1-p)$	p	$(1-p)$	p	$(1-p)$
1	0.30	0.70	0.35	0.65	0.40	0.60	0.45	0.55	0.50
2	0.090	0.490	0.122	0.422	0.160	0.360	0.205	0.303	0.250
3	0.0270	0.343	0.0429	0.275	0.0640	0.216	0.0912	0.166	0.1250
4	0.00810	0.240	0.0150	0.179	0.0262	0.130	0.0410	0.0915	0.06250
5	0.00243	0.168	0.525×10^{-2}	0.116	0.0102	0.0778	0.0185	0.0504	0.0313
6	0.729×10^{-3}	0.118	0.184×10^{-2}	0.0754	0.410×10^{-2}	0.0467	0.830×10^{-2}	0.0277	0.0156
7	0.219×10^{-3}	0.0823	0.643×10^{-3}	0.0490	0.164×10^{-2}	0.0280	0.374×10^{-2}	0.0152	0.781×10^{-2}
8	0.656×10^{-4}	0.0576	0.225×10^{-3}	0.0318	0.656×10^{-3}	0.0168	0.168×10^{-2}	0.838×10^{-2}	0.391×10^{-2}
9	0.197×10^{-4}	0.0403	0.788×10^{-4}	0.0207	0.262×10^{-3}	0.0101	0.758×10^{-3}	0.460×10^{-2}	0.195×10^{-2}
10	0.591×10^{-5}	0.0282	0.276×10^{-4}	0.0135	0.105×10^{-3}	0.604×10^{-2}	0.341×10^{-3}	0.253×10^{-2}	0.977×10^{-3}
11	0.177×10^{-5}	0.0197	0.965×10^{-5}	0.874×10^{-2}	0.420×10^{-4}	0.363×10^{-2}	0.153×10^{-3}	0.134×10^{-2}	0.488×10^{-3}
12	0.532×10^{-6}	0.0138	0.338×10^{-5}	0.568×10^{-2}	0.176×10^{-4}	0.218×10^{-2}	0.690×10^{-4}	0.766×10^{-3}	0.244×10^{-3}
13	0.159×10^{-6}	0.967×10^{-2}	0.118×10^{-5}	0.369×10^{-2}	0.706×10^{-5}	0.131×10^{-2}	0.310×10^{-4}	0.421×10^{-3}	0.122×10^{-3}
14	0.479×10^{-7}	0.676×10^{-2}	0.414×10^{-6}	0.240×10^{-2}	0.282×10^{-5}	0.783×10^{-3}	0.140×10^{-4}	0.232×10^{-3}	0.610×10^{-4}
15	0.144×10^{-7}	0.474×10^{-2}	0.145×10^{-6}	0.156×10^{-2}	0.113×10^{-5}	0.470×10^{-3}	0.628×10^{-5}	0.127×10^{-3}	0.305×10^{-4}
16	0.431×10^{-8}	0.332×10^{-2}	0.506×10^{-7}	0.101×10^{-2}	0.453×10^{-6}	0.282×10^{-3}	0.283×10^{-5}	0.700×10^{-4}	0.152×10^{-4}
17	0.129×10^{-9}	0.232×10^{-2}	0.175×10^{-7}	0.659×10^{-3}	0.181×10^{-6}	0.169×10^{-3}	0.127×10^{-5}	0.385×10^{-4}	0.763×10^{-5}
18	0.388×10^{-9}	0.163×10^{-2}	0.621×10^{-8}	0.428×10^{-3}	0.722×10^{-7}	0.102×10^{-3}	0.574×10^{-6}	0.212×10^{-4}	0.381×10^{-5}
19	0.116×10^{-9}	0.114×10^{-2}	0.217×10^{-8}	0.278×10^{-3}	0.288×10^{-7}	0.609×10^{-4}	0.258×10^{-6}	0.117×10^{-4}	0.141×10^{-5}
20	0.348×10^{-9}	0.796×10^{-3}	0.761×10^{-9}	0.181×10^{-3}	0.116×10^{-7}	0.365×10^{-4}	0.116×10^{-6}	0.640×10^{-5}	0.704×10^{-6}

become quite cumbersome, but in such cases the equivalent duty cycle curve (the H curves in Figs. 5 and 5A) approaches so nearly to a straight line that the demand frequency may be determined with sufficient accuracy by the method given in "Standardized Flexible Distributing Systems in Industrial Plants," *General Electric Review*, Vol. 21, p. 176-285. Indeed, this method may be used for values of N less than 20 if p is sufficiently large, say if $N\,p$ is 10 or more and if R is 1000 or more.

TABLE V—1.

Values of ${}^{N}C_r = \dfrac{N\,(N-1)\,(N-2)\,.\,.\,.\,.\,(N-r+1)}{r\,(r-1)\,(r-2)\,.\,.\,.\,.\,1.}$

r	$N=3$	$N=4$	$N=5$	$N=6$	$N=7$	$N=8$
1	3	4	5	6	7	8
2	3	6	10	15	24	28
3	1	4	10	20	35	56
4		1	5	15	35	70
5			1	6	24	56
6				1	7	28
7					1	8
8						1
r	$N=9$	$N=10$	$N=11$	$N=12$	$N=13$	$N=14$
1	9	10	11	12	13	14
2	36	45	55	66	78	91
3	84	120	165	220	286	364
4	126	210	330	495	715	1001
5	126	252	462	792	1278	2002
6	84	210	462	924	1716	3003
7	36	120	330	792	1716	3432
8	9	45	165	495	1278	3003
9	1	10	55	220	715	2002
10		1	11	66	286	1001
11			1	12	78	364
12				1	13	91
13					1	14
14						1

TABLE V—2.

Values of ${}^{N}C_r = \dfrac{N\,(N-1)\,(N-2)\,.\,.\,.\,.\,(N-r+1)}{r\,(r-1)\,(r-2)\,.\,.\,.\,.\,1}$

r	$N=15$	$N=16$	$N=17$	$N=18$	$N=19$	$N=20$
1	15	16	17	18	19	20
2	105	120	136	153	171	190
3	455	560	680	816	969	1140
4	1365	1820	2380	3060	3876	4845
5	3003	4368	6188	12816	11628	15504
6	5005	8008	12376	18564	27132	38760
7	6435	11440	19448	31824	50388	77520
8	6435	12870	24310	43758	75582	127970
9	5005	11440	24310	48620	92378	167951
10	3003	8008	19448	43758	92378	184756
11	1365	4368	12376	31824	75582	167951
12	455	1820	6188	18564	50388	127970
13	105	560	2380	12816	27132	77520
14	15	120	680	3060	11628	38760
15	1	16	136	816	3876	15504
16		1	17	153	969	4845
17			1	18	171	1140
18				1	19	190
19					1	20
20						1

Frequency tables (VI-1, VI-2, and VI-3) giving values of ${}^{N}C_r\,p^r\,(1-p)^{N-r}$ are included for $N = 5$, 10, 15, 20, and, in each case, for $p = 0.10$, 0.25, 0.50, 0.75, 0.90. From these typical group duty cycles for $P = 1.0$, $i = 1.0$ may be plotted and the correspond-

TABLE VI—1.

Frequency Tables: Values of $P_r = {}^{N}C_r\,p^r\,(1-p)^{N-r}$.

I. $N = 5$

r	$p=0.10$	$p=0.25$	$p=0.50$	$p=0.75$	$p=0.90$
0	0.59	0.24	0.031	0.001	0.1×10^{-4}
1	0.330	0.400	0.155	0.014	0.45×10^{-3}
2	0.073	0.265	0.310	0.080	0.0081
3	0.0081	0.080	0.310	0.265	0.073
4	0.45×10^{-3}	0.014	0.155	0.400	0.330
5	0.1×10^{-4}	0.001	0.031	0.240	0.590

II. $N = 10$

r	$p=0.10$	$p=0.25$	$p=0.50$	$p=0.75$	$p=0.90$
0	0.35	0.0575	0.001	0.1×10^{-4}	0.1×10^{-9}
1	0.390	0.19	0.010	0.3×10^{-4}	0.9×10^{-8}
2	0.194	0.286	0.044	0.4×10^{-3}	0.36×10^{-6}
3	0.0576	0.264	0.1175	0.3×10^{-2}	0.86×10^{-5}
4	0.0114	0.147	0.206	0.017	0.14×10^{-3}
5	0.15×10^{-2}	0.031	0.247	0.031	0.15×10^{-2}
6	0.14×10^{-3}	0.017	0.206	0.147	0.0114
7	0.86×10^{-5}	0.3×10^{-2}	0.1175	0.264	0.0576
8	0.36×10^{-6}	0.4×10^{-3}	0.044	0.286	0.194
9	0.9×10^{-8}	0.3×10^{-4}	0.010	0.192	0.390
10	0.1×10^{-9}	0.1×10^{-4}	0.001	0.0575	0.35

TABLE VI—2.

Frequency Tables: Values of $P_r = {}^{N}C_r\,p^r\,(1-p)^{N-r}$.

III. $N = 15$

r	$p=0.10$	$p=0.25$	$p=0.50$	$p=0.75$	$p=0.90$
0	0.21	0.0135	0.3×10^{-4}	0.1×10^{-8}	0.1×10^{-13}
1	0.345	0.068	0.0005	0.4×10^{-7}	0.1×10^{-11}
2	0.268	0.164	0.003	0.9×10^{-6}	0.9×10^{-9}
3	0.132	0.232	0.014	0.1×10^{-4}	0.3×10^{-8}
4	0.044	0.232	0.043	0.1×10^{-3}	0.9×10^{-7}
5	0.011	0.174	0.093	0.7×10^{-3}	0.2×10^{-6}
6	0.002	0.095	0.155	0.004	0.3×10^{-5}
7	0.3×10^{-3}	0.041	0.120	0.014	0.3×10^{-4}
8	0.3×10^{-4}	0.014	0.120	0.041	0.28×10^{-3}
9	0.3×10^{-5}	0.004	0.155	0.095	0.002
10	0.2×10^{-6}	0.7×10^{-3}	0.093	0.174	0.011
11	0.9×10^{-7}	0.1×10^{-3}	0.043	0.232	0.044
12	0.3×10^{-8}	0.1×10^{-4}	0.014	0.232	0.132
13	0.9×10^{-9}	0.9×10^{-5}	0.003	0.164	0.268
14	0.1×10^{-11}	0.4×10^{-7}	0.5×10^{-3}	0.068	0.345
15	0.1×10^{-13}	0.1×10^{-8}	0.3×10^{-4}	0.014	0.210

TABLE VI—3.

Frequency Tables. Values of $P_r = {}^{N}C_r\,p^r\,(1-p)^{N-r}$.

IV. $N = 20$. (Values of P involving $\delta\,0.10 \times 10^{-5}$ and less omitted)

r	$p=0.10$	$p=0.25$	$p=0.50$	$p=0.75$	$p=0.90$
0	0.13	0.32×10^{-2}	0.86×10^{-6}		
1	0.270	0.022	0.17×10^{-4}		
2	0.270	0.067	0.16×10^{-3}		
3	0.184	0.137	0.95×10^{-3}		
4	0.092	0.170	0.40×10^{-2}		
5	0.033	0.200	0.0126	0.36×10^{-5}	
6	0.89×10^{-2}	0.160	0.031	0.27×10^{-4}	
7	0.19×10^{-2}	0.116	0.062	0.15×10^{-3}	
8	0.36×10^{-3}	0.061	0.103	0.77×10^{-3}	
9	0.52×10^{-4}	0.027	0.136	0.32×10^{-2}	
10	0.65×10^{-5}	0.010	0.150	0.010	0.65×10^{-5}
11		0.32×10^{-2}	0.136	0.027	0.52×10^{-4}
12		0.77×10^{-3}	0.103	0.061	0.36×10^{-3}
13		0.15×10^{-3}	0.062	0.116	0.19×10^{-2}
14		0.27×10^{-4}	0.031	0.170	0.89×10^{-2}
15		0.36×10^{-5}	0.0126	0.210	0.033
16			0.40×10^{-2}	0.180	0.092
17			0.95×10^{-3}	0.137	0.184
18			0.16×10^{-3}	0.067	0.270
19			0.17×10^{-4}	0.022	0.270
20			0.86×10^{-6}	0.0032	0.130

ing H curves drawn for comparison with similarly grouped graphical instrument records (See Fig. 3A).

The following tables (VII-1, and VII-2) giving values of $p_r^{1/2}$ and $c\,p_s^{1/2}$, for various values of p_r, c, and p_s, within the ordinary range of duty cycles, may be useful in computing values of *duty cycle factors* (See section on Temperature Rating above).

Thus if observation determines the values of $p_r = 0.65$, $c = 0.75$, and $p_s = 0.15$, then in Table VII-1 find $p_r^{1/2} = 0.81$, and in Table VII-2, opposite $p_s = 0.15$, and under $c = 0.75$, find $c\,p_s^{1/2} = 0.29$. The corresponding duty cycle factor is $d = 0.81 + 0.29 = 1.10$.

TABLE VII—1.
Duty Cycle Factors

p_r =	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	
$p_r^{1/2}$ =	0.14	0.18	0.20	0.22	0.25	0.27	0.28	0.30	
p_r =	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	
$p_r^{1/2}$ =	0.32	0.39	0.45	0.50	0.55	0.59	0.63	0.67	
p_r =	0.50	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90
$p_r^{1/2}$ =	0.71	0.74	0.78	0.81	0.84	0.87	0.90	0.92	0.95

TABLE VII—2.
Duty Cycle Factors

C =	0.25	0.50	0.75	1.00	1.25	1.50
p_s	$c\,p_s^{1/2}$	$c\,p_s^{1/2}$	$c\,p_s^{1/2}$	$c\,p_s^{1/2}$	$c\,p_s^{1/2}$	$c\,p_s^{1/2}$
0.02	0.04	0.07	0.11	0.14	0.18	0.21
0.03	0.04	0.09	0.13	0.18	0.22	0.27
0.04	0.05	0.10	0.15	0.20	0.25	0.30
0.05	0.06	0.11	0.17	0.22	0.28	0.34
0.06	0.06	0.12	0.18	0.25	0.31	0.37
0.07	0.07	0.13	0.20	0.27	0.33	0.40
0.08	0.07	0.14	0.21	0.28	0.35	0.43
0.09	0.08	0.15	0.22	0.30	0.38	0.45
0.10	0.08	0.16	0.24	0.32	0.40	0.48
0.15	0.10	0.19	0.29	0.39	0.49	0.58
0.20	0.11	0.22	0.34	0.45	0.56	0.67
0.25	0.13	0.25	0.38	0.50	0.63	0.75
0.30	0.14	0.28	0.41	0.55	0.69	0.83
0.35	0.15	0.30	0.44	0.59	0.74	0.89
0.40	0.16	0.32	0.47	0.63	0.79	0.95
0.45	0.17	0.34	0.50	0.67	0.84	1.00
0.50	0.18	0.35	0.53	0.71	0.88	1.10

HYDROELECTRIC DEVELOPMENT ON THE AMERICAN RIVER

A license for a comprehensive power development on the South Fork of the American River, in the vicinity of Placerville, California, has been issued to the El Dorado Power Co., a subsidiary of the Western States Gas and Electric Co.

The project as proposed utilizes an existing canal, 25 miles in length, known as the El Dorado Ditch which will divert water from the American River, a short distance below its confluence with Silver Fork. The canal will be enlarged from a capacity of 40 cubic feet per second to 350 cubic feet per second. From the canal the water will be conducted through a three-mile conduit to the penstocks which supply the turbines to be located in a power house on the American River about one mile below the mouth of Silver Creek. The turbines will operate under a head of 1900 feet. The company plans an ultimate installation of 100,000 horse power to be developed in four stages.

The project includes six storage reservoirs on the headwaters of American River, with an ultimate capacity of 90,000 acre-feet. Three of the reservoirs, to the capacity already constructed, are included in the license for Project No. 78, which was recently issued to the Western States Gas and Electric Co. The El Dorado Power Co. will acquire all water and property rights involved in these reservoirs, and the present license will be amended to include them.

The public hearings on this project brought out data showing that the greatest economic use for irrigation purposes alone demanded that as much as possible of the water on the upper American River be used for power. By generating electric energy in the mountains and transmitting it to the highly productive agricultural area in the vicinity of Stockton, about three acres per horse power can be irrigated by electric pumping. If the water necessary to produce the electric energy were to be diverted to irrigation uses in the upper American River drainage, the equivalent usefulness of the water would be one acre per horse power. Furthermore, but little of the water diverted to irrigation use on the upper American River drainage could again be productively used, whereas the same water, if used to generate electricity can be used again for the same purpose at a plant lower down on the stream.



The Nature of Tribo-Electricity or Electricity of Friction and other Kindred Matters.

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BEFORE the days of the discovery of the voltaic battery or the generation of electricity by contact of two different metals, the only source of electricity and the only knowledge which we had or which the world possessed depended on the development of electrical charges on the surfaces of non-conductors by friction. At least, the charges were the accompaniment of friction, the earliest manifestation of which was the ancient observation of Thales that amber (electron) when rubbed would attract light bodies. In the early part of the eighteenth century, experimentation in this field of the generation of electricity by friction really led to the discovery of some of the most fundamental principles of the science, such as the division of substances into conductors and non-conductors, electrics and dielectrics, positive and negative charges, and discharges uniting the two. Von Guericke constructed an electrical generator and frictional machine consisting of a revolving globe of sulphur, rubbed generally by the hand, while Franklin carried on many of his original experiments by the rubbing of glass rods or tubes, using fibrous material or fur as a rubber, and Franklin's famous machine for the generation of electricity was the well-known form consisting of a revolving glass sphere provided with a rubber on the one end of the diameter, and a collector at the other end communicating a charge from the rubbing surface of the globe to what was known as the "prime conductor." This machine was soon succeeded by the revolving glass cylinder of the cylinder machine, which, in the hands of Ramsden, Von Marum, and others, became modified into the plate machine, where a circular glass plate instead of a cylinder was mounted so as to be rubbed on both sides, while the collector was a set of points on both sides connected with a prime conductor. The glass plate was found to be superior to the cylinder. I have not, however, noticed any reason having been given for this in the literature with which I am acquainted, other than that the plate gave the possibility of a greater velocity of travel, and with it gave greater length of rubbing surfaces in moderate space, since both sides were rubbed. It had been noticed that if the revolving plate was too thick it was not as effective as when it was of moderate thickness. We can now readily ascribe the true cause for the superiority of the plate machine in that when both sides were subjected to the action of the rubber, and if the sides were not too far apart, as would be the case in too thick a plate, the electrification would inductively act through the plate, or more properly, the capacity of the plate after it left the rubber would be less than in the case of the cylinder where only one side of the glass was charged by the friction, which charge would tend to bind to itself through the glass an opposite charge on the other side. There could not, therefore, be, when the glass left the rubber, anything like the elevation of potential, which must occur in the case of the plate, for be it understood that when the rubber and the glass surfaces are in contact, the electricity developed is "bound," and does not manifest itself until the separation of the charges by the movement of rotation, attended by an enormous change of capacity leading by the diminution of capacity to the electrification taking on a high tension or voltage.

Further on, this action of changed capacity will be analyzed, and in it will be found the secret of the high tension or high voltage producible in the so-called "frictional" apparatus. It was early found, however, that for example the pressure of a dry cork on a glass surface, or other smooth surface, gave rise to the separation of electricities, such that the cork acquired a charge on the surface which had been in contact with the glass, while the glass surface had acquired an opposite charge. It was found that other substances could be pressed against smooth surfaces and removed with the possession of a charge. It was then discovered that a piece of glass plate dipped into clean, dry mercury, and removed, came away with its surface highly charged. Here, then, was electrification without any considerable friction. This experiment with mercury led later to the introduction of some mercury into a tube which had been exhausted by an air pump, and sealed, with the result that on shaking such a tube in the dark, the electrification of the glass by the running of the mercury over the surface would, in neutralizing itself, together with the charge which the mercury acquired, illuminate the interior of the tube in much the same way that the Geissler tube is illuminated by the passage of an electric discharge. It was this observation of the effect of dipping glass into the clean, dry mercury which led to the use of mercury amalgams of tin or zinc as a facing for the rubbers on the cylinder, or plate type of so-called "frictional machines," and in my early experience I used the tin mercury amalgam scraped from the back of the old-fashioned looking glass, which was made into a paste with a little grease, and spread upon the rubber, with the result of greatly enhancing the output and the voltage of the frictional charge, so called. It was later found that bisulphide of tin, known commer-

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cially as "Mosaic Gold" (on account of its golden appearance) was, if anything, more effective than mercury amalgams as a facing for the rubbers. Now, these expedients of facings, while they enhanced the effect greatly, did not increase the friction, but, in fact, diminished it. Further, an increase of pressure of the rubbers beyond a certain point did not increase the electricity generated, but did increase the friction greatly, and might be made so great as to cause heating. Evidently, then, the term "frictional electricity" is not a proper one, since an increase of pressure increasing the friction did not, when it exceeded that amount which was required to make a close contact, have any perceptible effect on the electrical output. The output, however, of the early frictional types of machines could be greatly increased by speeding them up, but when we speak of output in this connection, we mean not an increase of voltage or tension, as it was formerly called, but an increase of the charging capacity, say in large Leyden jars or condensers. In these days, we would practically say that the current output was increased, but the natural current output in such machines was so small as to be immeasurably small by any instruments then known. The so-called static machines of the early days, therefore, were simply means of obtaining electricity of comparatively high tension representing an exceedingly small output of energy, and it was not until about two-thirds of the nineteenth century had passed by when such machines as the Holtz influence machine were produced that there was any possibility in view of obtaining a measurable current. With an influence machine, however, of say a dozen plates, all actively at work and revolving at a fair rate, the output becomes measureable by a milliammeter.

What has been said in the above leads to a consideration of the development of electricity as due to something different from friction, and makes the term "frictional electricity" or "tribo-electricity" as it is sometimes called, hardly applicable in the strict sense.

Reference has been made to the electrification caused by dipping a glass plate into clean, dry mercury, but if we take a turpentine varnish as a film and dry it upon metal or glass, and use enough varnish so that it becomes of such thickness as to be stripped off when nearly dry, it will be found that such a film comes away from the metal or glass in a high state of charge, so that it will stick to any surface nearby by electrostatic attraction. The same is true when a collodion film is dried against a glass surface and stripped off. Here, the pyroxyline comes away in a high state of charge. Such actions do not involve friction. The shavings from a wood plane, when the air is dry and the wood very dry, are even very highly electrified, and even paring wood with a knife gives chips under similar conditions which are charged. Combing the hair, brushing surfaces, scuffling over a carpet, result in a separation of electrical charges. Even the movement of a belt over a smooth pulley, if the belt be dry and the surrounding air be dry, will often give rise to the very decided manifestation of an electrical charge, as the belt moves away from the pulley surfaces, and, in fact, in the presence of gasoline or alcohol vapors, a moving belt is often a source of great danger of fire. The electricity developed in belts has often been attributed to the friction on the pulley, but it is a notable fact that even when the belt is not slipping, a charge is developed and is not notably increased if the belt does slip. The true state of the case is that such electrification is developed as in the case of the varnish or collodion film by the mere contact of the belt with the pulley surface rolling off it, and as it rolls away, there is a great reduction of the capacity of the system, so that the charge which is bound to its opposite when the belt is upon the pulley is separated with great reduction of capacity, and consequent enormous increase of its tension or potential. In this view of the case, manifestly the belt action is no different from that of the early frictional machines. The friction in these early frictional machines becomes evident as a means of merely getting a continued contact and separation. A reduction of capacity and rise of potential is the consequence thereof.

Let us look, for a moment, into the action of fur or a collection of hairs or fibers as a rubber. It is known to be quite effective in obtaining what are called frictional charges, but the case is no different from that of the belt. The fur fibers roll upon the surface of glass (assuming that to be the medium rubbed) and different parts of the hair in this way come in contact and become charged, the rolling action being somewhat like the rolling of the belt over the pulley. The fur then presents a charged surface much larger than a flat surface would present to electrification by *contact*, not *friction*. The friction merely rolls the fibers about and insures their receiving on all sides the contact charge. We are now ready to take another step in the understanding of the matter. When Galvani noticed the effect of metal in causing the convulsion of the frog's leg muscles, Volta took up the matter, and showed that the contact of two metals and the generation by the mere fact of contact of an electrical difference of potential between them would account for the frog's leg contraction. It was on this basis that the voltaic battery was developed. It came practically out of Volta's work, but it was with some difficulty that Volta was able to prove that such a pair of metals as say copper and zinc, or zinc and gold, by merely being placed together would generate an electromotive force, and he invented his condenser electroscope for the purpose of making the proof. This today might be called an amplifier of charges. He arranged a condenser so that it would be charged by the contact of one of its sides, say with copper, and the other with zinc of a pair or couple united. In this case he obtained a charge in the condenser but of such low voltage that it was not to be detected by any ordinary means.

However, by lifting one of the plates of the condenser from the other, the capacity of the system underwent such a very large change that the one volt charge became many volts, and manifested itself by deflecting a gold leaf electroscope in connection with one of the condenser plates, kept insulated, of course, during the test. It was this admirable device of Volta which really made it possible for him to show that the contact of dissimilar metals was sufficient to cause electrification. Volta's ideas were criticised when it was shown that the convulsion in the frog's leg could be obtained without using two metals. He then modified his theory after considerable experimentation, and broadened the statement, so that it became "contact between heterogeneous materials is attended by separation of the electricities." Now, if it were possible to lay a sheet of zinc upon a sheet of copper, and have the surfaces very close, almost, say, molecularly close, we would have the zinc positive and the copper negative, or the difference of potential would be one volt approximately. If, now, these parallel sheets could be lifted away from each other so that the motion, say, was absolutely the same at all points, we would get the effect of the Volta condenser electroscope; that is, as the metals separated, the voltage difference between them would rise. This is, however, not possible in the case of conductors which easily short-circuit. It is possible even with irregular separation only when one of them at least is a good non-conductor, because in this case any development of an increased potential can not distribute itself to other parts and short-circuit the system.

Let us assume that two materials, say a collodion film upon a glass surface, or varnish film upon a smooth metal surface, have, according to Volta's principle, a small difference of potential at the contact. Assume it to be two or three volts only. The distance apart is molecular. It would be far below one-millionth of an inch, or even one-millionth of a millimeter. If we double that almost infinitesimal distance, the voltage rises to double, if the surfaces are fairly large. If we double it again, the voltage will again double, etc. It will evidently take a great many doublings of such a small distance to given any perceptible separation, and as at each doubling the voltage rises almost in proportion, the voltage which was at first small (as two or three volts) to begin with, may now become many thousand. Here, then, I think we have the secret of the generation of high-tension electricity, due not to friction, but to contact through the agency of friction and effects due to contact without the agency of friction. To a limited extent, the spreading charge effect from sides and edges soon comes in to lessen the increase of potential and limits the lowering of capacity as the charged bodies are separated more and more. At last we reach a separation which if increased gives hardly any further lowering of the capacity. The limit of rise of potential then has been reached largely through the edge effect. We are now in a position to understand why it is that a narrow dry belt of leather leaves a pulley and acquires only a moderate potential, even when the surrounding air is very dry. It does not yield anything like the potential that is obtained from a much wider belt under similar circumstances. Moreover, if the belt runs over too small a pulley, the separation of the belt from it is too abrupt, and a recombination of the electricity of the belt with that of the pulley surfaces of opposite name takes place as the belt is leaving. When the diameter of the pulley is large, the separation is not so rapid, and the recombination cannot take place so readily. I remember occasions when it was easily possible to obtain spark discharges of eight or ten inches in length from a moderate-size belt running over a smooth pulley, but in the case of a very wide belt, such as four or five feet or more in width, I have noticed occasions when such a belt would give sparks over four or five feet, indicating the presence of an enormous voltage, possibly as much as 1,000,000 volts or more. Here the charges on the surfaces acquired by contact were gradually separated, and the change in capacity effect was so slight that the potential kept rising without disruptive sparks as the belt left the pulley surface, followed by reduction of capacity. In fact, the potential rise was so gradually increased that the belt and pulley did not spark one to the other or short-circuit over the increasing space between them. The separation was made at a rate safe enough to conserve the charge on the belt. Here, then, was an accidentally constituted static machine on a grand scale and operating without friction, but by the mere rolling of the pulley on the belt, so to speak, or by the rolling of the belt over the pulley, perhaps, to state the matter more accurately.

There are many reasons for believing that the arrangement of the molecules at the bounding surfaces of bodies is different in many cases from the interior arrangement. The remarkable phenomena of surface tension are to be explained on this basis. Dr. Irving Langmuir in some of his investigations has shown the tendency of some of the molecules, in liquids especially, to present themselves in a manner so that certain groups of atomic constituents may be presented outwardly. There is no time to go into details of these investigations, but they tend to show that the surface conditions bulk large in many of the phenomena of nature. Surface actions are often spoken of as due to surface tension, a particular kind of polarization of the surface. When two surfaces are brought together, therefore, so intimately that one can imagine the molecules approaching close enough so as to intrude on each other's spheres of influence, it should not be difficult, in accordance with the electrical theory of matter, to infer differences of electrical state existing at contacts, especially when the substances themselves are very different, as when the contact, according to Volta, is of heterogeneous materials. The contacting surfaces acquire a certain

sort of electrical equilibrium which involves the existence of the plus or minus charges in a bound state between the two surfaces, and possible exchange of electrons.

We may say that electrons are displaced in the process such that one body loses negative electrons and become positive, and the other gains the lost electrons. During incipient separation the charges continue to be measurably bound, but cannot reunite across the space of separation on account of the air insulation which has been established between them. As the separation is attended with lowered capacity, the potential rises. The intimate relation which exists between the surface tension and the electrical state is well exemplified in numerous experiments. Among them may be mentioned the well-known phenomenon of "variations of mercury surface tension by electrification" discovered by Lippmann. It may also be mentioned in conclusion that the old Armstrong hydroelectric machine whereby steam, issuing from a boiler, produces a cloud in a high state of electrification, resembling a thunder cloud on a small scale, is probably dependent upon modification of surfaces or surface tension, and lastly, the investigation of Simpson into the nature of the separation of electricity in a thunder cloud leads us to the consideration of the surface of the rain drops undergoing modification and separation of electricities in two parts of the cloud. It is, however, not the present intention to deal with this phase of the subject, but to point out in an emphatic way that to begin the study of electricity perhaps the most suitable procedure would be the study of Volta's contact theory and its application, not only to the Voltaic battery operation, but also to the much older methods of developing electric charge, as by the contact machines long called "frictional."

It may be said in conclusion that it is probably that there is no such thing as frictional electricity, as distinguished from that produced at the contact of dissimilar surfaces. On this basis, we can dispense with the term "tribo-electricity."

EMPLOYERS URGED TO PAY FOR VISION CORRECTION

At the convention of the National Association of Cost Accountants in Cleveland a short time ago, Mr. L. W. Wallace of Washington urged manufacturers to pay for treating defective eyesight among their employees, on the ground that increased production will warrant it. Mr. Wallace is vice-chairman of a special committee on waste in industry appointed by Herbert Hoover. In the course of his address, he declared that there are 25,000,000 workers in this country who have defective vision which requires correction.

Such a condition serves to emphasize the need for proper adequate lighting in the industries. A certain percentage of all defective vision is attributable, in the first place, to poor lighting. Aside from any motive of personal gain, it is the moral duty of employers to see that the possibilities of impairing the eyesight of employees in their plants and factories are minimized. Disregarding the shortcomings of the past, however, it is not difficult to believe that if the defective vision now existing among 25,000,000 workers were corrected at the expense of those employing them the increased production resulting would well warrant the expenditure.

AUTOMATIC INDUCTION VOLTAGE REGULATORS FOR A-C. LIGHTING CIRCUITS

The desirability of burning incandescent lamps at the voltages at which they are rated, and the harmful effect of even a slight voltage variation upon efficiency, lumen output and lamp life, are subjects with which most electrical engineers are very familiar. When the voltage supplied at the lamp socket fluctuates, as is often the case where the lighting and power load are both on the same feeder, the problem of securing a correct, constant voltage on the lighting circuit cannot be solved as easily as when the voltage supplied is constant, but somewhat below or above the voltage rating of the lamps. Temporary departures of one or two volts from the voltage rating of the lamps on such circuits will have no serious effect on the lighting system, but when variations as great as 10 per cent above and below normal voltage are experienced, as is the case in such places as workshops with variable load demands on the feeders, good lighting requires some form of voltage regulation.

In such cases, where the source of supply is alternating current, an automatic induction voltage regulator should be installed. These regulators are essentially variable ratio transformers, having two separate windings connected respectively in series with and across the circuit to be regulated. The windings are assembled on separate concentric sheet-iron cores, one core being stationary and the other arranged so that it can be rotated within the former. The variation in voltage produced by the regulator is due entirely to the change in the angular position of these cores.

The voltage regulators are built single-phase and polyphase and are designed to operate on practically all sizes of systems encountered today. Once installed, they are entirely automatic in their action and require no further attention. From the standpoint of lighting, they are most useful in controlling the voltage of lighting loads which are on the same feeder with power loads. They are also helpful in effecting economies in feeder installation costs, since their use often allows the selection of a smaller size conductor. All standard regulators have a voltage range of 10 per cent boost and 10 per cent lower, and are therefore capable of taking care of a 20 per cent voltage range on a given circuit. On a 1000-kw. circuit the size of regulator necessary would be 100 kw.

Higher Steam Pressures or Pulverized Coal?

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The author assumes a hypothetical power or public service steam plant of 100,000-kw. nominal capacity and compares the cost of operation of such a plant on a basis of 250 lb. pressure and 600 deg. fahr. total steam temperature, and 400 lb. pressure and 700 deg. fahr. total steam temperature, when fired by stokers and pulverized coal.

The results of the comparison indicate that, with much lower capital costs, even better thermal plant efficiency will pertain with the use of pulverized coal and the lower steam pressure than would be the case with the higher steam pressure plant, stoker fired.

TWO years ago, when the Edison Association of Illuminating Companies held its Annual Meeting at New London, Conn., the technical section developed a discussion as to what should be done with a view to lowering the cost of producing a kw-hour, which was at that time over 100 per cent greater than before the World War.

Various suggestions were made by engineers and others present, one statement being that the boiler pressure should be increased to 400 or 500 lb. Another official and engineer of a large public service corporation in the East quite emphatically made the statement that the only way to reduce these costs, in his opinion, would be to use pulverized coal and he predicted that in two years time this practise would begin to be generally used.

The writer, in discussing this subject, predicted that the excessive cost of the high-pressure idea would prevent a realization of lower costs, on account of the additional capital or fixed charges absorbing any gain which would be made from better thermal efficiency of the plant, and also said that rough figures would show that the desired results would be more likely to be obtained if only a portion of the additional expense involved was used in equipping the plant to use pulverized coal.

This question of higher pressures and temperatures is still a mooted one and is quite thoroughly discussed in a most excellent manner in a paper presented by Col. C. F. Hirshfeld, Chief Research Dept., of the Detroit Edison Co., before the Cleveland Section of the A. S. M. E. in March 1921. In this paper the author states that it is "his personal opinion that 700 deg. fahr. is about as high as we can safely go at present" and suggests a working pressure of steam at 400 lb.

As it is quite evident that there must be some point where the capital costs and fixed charges accompanying same will prohibit the reduction of the present kw-hr. cost from being benefited thereby, the author has made a study of the question from an investment and operating standpoint, comparing the present average practise as to pressures and temperatures with the above suggested 400 lb. pressure and 700 deg. final temperature. The basis on which the following estimates are made is as follows:

Capacity of plant, 100,000 kw.; consisting of four 25,000-kw. units and twelve 1600-h. p. boiler units (19,200 rated boiler h. p.) or approximately 5 kw. per boiler h. p.

As we are primarily interested more particularly in the *difference* in cost between the present average practise and the higher pressures, we have made a study of the various items entering into the costs of both suggestions, consulting with prominent manufacturers in order to obtain this information, which may be considered authentic and reasonable. For the lower pressures and temperatures we have adopted 250 lb. and 600 deg. fahr. temperature. For the higher, as above stated, 400 lb. and 700 deg. fahr. temperature. The items which are affected by the increase of pressure and the additional expense involved, due to the difference in pressure and temperature, are as follows:

(a)	Difference in	cost of boilers and superheaters 19,200 h. p. at $13 per h. p., or $2.49 per kw., including freight and erecting charges	$249,600
(b)	"	in economizers $4 per h. p. or $0.768 per kw.	76,800
(c)	"	in steam turbines 100,000 kw. @ $2 per kw.	200,000
(d)	"	in steam piping, forged valves and pipe covering at $2 per kw.	200,000
(e)	"	in feed pumps and auxiliary apparatus 50 cents per kw.	50,000
		Estimated total difference in cost	$776,400

The average water rate of the turbines at 250 lb. pressure is assumed to be 10¾ lb. per kw-hr. and at 400 lb. pressure, 10 lb. per kw-hr., and an allowance of 5 per cent for additional power or steam for auxiliaries.

In the operation of the plant we have adopted an annual load factor of 40 per cent and a fair average bituminous coal has been assumed in both cases of 13,000 B. t. u., and 8 per cent of ash and the combined boiler furnace and economizer efficiency with stokers at 78 per cent, and with pulverized coal an equivalent efficiency of 85 per cent. The following costs have been used:

Cost of coal delivered $5 per long ton.
Cost of power ¾ cent per kw-hr.
Cost of common labor 40 cents an hour.

In the operating costs we have omitted taking into consideration the firing room labor, as these items would be practically identical in either case.

With the above items fixed, the steam requirements

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per hour for the 250-lb. pressure plant will be 451,500 lb., which translated into steam per hour from and at 212 deg. is equivalent to 569,793 lb. For the 400-lb. pressure plant these figures are 420,000 lb. and 547,260 lb. respectively.

Additional data may be determined from the foregoing as follows:

Item	250 Lb. Press. Plant Col. 1 Stoker fired	Col. 2 Pulv. coal fired		400 Lb. Press. Plant Col. 3 Stoker fired	Col. 4 Pulv. coal fired
(1) lb. coal per kw-hr.	1.36	1.25		1.31	1.214
(2) B. t. u. per kw-hr.	17680	16250		17030	15782
(3) Thermal eff. of plant-per cent	19.31	21.20		20.22	21.75
(4) Evap. per lb. coal from and at 212 deg. fahr.	10.43	11.27		10.43	11.27
(5) Fuel, tons per hr.	24.40	22.36		23.42	21.23
(6) Fuel cost per hr.	$122.00	$111.80		$117.10	$106.15
(7) Fuel cost per day	$2928.00	$2683.00		$2810.40	$2547.60
(8) Repairs ($1.50 per rated h. p. per year) per day	78.80		Pulv., dyring, repairs, labor, power,	78.80	
(9) Power for operating stokers, air supply, coal handling 4 per cent	117.00	204.00	conveying and air supply 34c. ton*	117.00	198.22
(10) Fixed charges 12 per cent per yr. on $422,400 incl. coal bunkers and conveying and ash handling, stokers and air supply	138.00	141.00	Fixed chgs. pulv. coal plant, conveying system, bunkers, coal burning equip. air supply ash handling. Cost $476,000 inc. $60,000 for bldg.	138.00	141.00
(11) Ash removal 48 tons @ 25 cents	12.00	4.00	4 tons day av.	12.00	4.00
(12) Total cost per day, Items 7, 8, 9, 10 and 11	A-$3273.80	B-$3032.20		C-$3156.20	D-$2890.82
			Additional fixed chgs. @ 12 per cent. (See below)—per day	250.60	250.60
			Additional maintainence charges (See below) per day	21.25	21.25
			Actual total daily costs Col. 3 and 4	C′ 3428.05	D′ 3162.67

*These costs are based on pulverizing thousands of tons of bituminous coal and are, consequently, accurate. The items are as follows: Per net ton

Repairs—complete system	8	cents	per	ton
Power for all operation @ ¾ cents Kw-hr. (17 Kw-hr.)	12¾	"	"	"
Drying	6¼	"	"	"
Labor	7	"	"	"
Total	34	"	"	"

The cost of operation per diem in Col. 3, letter *C*, $3156.20, is not entirely complete as to this cost should be added the additional fixed charges due to the cost of the 400-lb. pressure plant as compared with the 250-lb. pressure plant, which, as previously shown will be $776,400. The per diem interest charges on this amount at 12 per cent equals $250.60.

Furthermore, there will be additional maintenance costs, due to the higher pressures and superheat, which may be taken as 1 per cent. The per diem cost of this item will be $21.25. These two daily costs added to the above item *C* is $3156.20 + 250.60 + 21.25 equal *C′* $3428.05. This is consequently, the total, daily operating and fixed charges cost of the plant, so far as it refers to the furnace equipment, for the 400-lb. pressure plant.

Comparing this with the daily operating costs of the 250-lb. pressure plant fired with pulverized coal, Col. 2, Item 12, *B*—$3032.20, it will be noted there is a difference of $395.85 which constitutes the saving which would be effected by the use of pulverized coal and this is equal to $144,485 per year.

These figures demonstrate therefore, that under the same operating conditions the high-pressure cost of operation as compared with pulverized coal on the low-pressure plant will be over $144,000 more per year and the thermal efficiency of the plant will be better with pulverized coal (17030 − 16250) by 780 B. t. u. per kw-hr., or reduced to percentage of B. t. u. in the coal utilized, the difference is nearly 1 per cent (21.20—20.26).

The estimate shows that the pulverized coal plant and necessary storage and burning equipment, auxiliaries and distributing system, etc. can be built in a substantial manner for approximately $476,000 (at present prices, Dec. 1921), of which $60,000 is allowed for a separate building (42 ft. by 144 ft.) for the milling and drying plant, having a capacity of 750 to 800 net tons of pulverized coal per day. This cost is only slightly more than the complete stoker equipment with distributing system, auxiliaries etc. installed. The costs of these equipments would be the same for both the 250 lb. and 400 lb. pressure plants.

The question might be raised as to the basis on which these estimates have been made in regard to thermal, boiler and furnace efficiencies. The author believes he is quite safe in stating that at the present time there is no plant in this country at any rate, operating on a B. t. u. basis of 17,680, stoker fired, as shown in Column 1 of above tables, although plans have been laid down for one or two power houses not yet in operation to give these results, so that this figure would indicate the best possible practise that can be obtained under the assumed load factor and other conditions of a plant of this size and pressure.

On the other hand, actual performance of boilers fired with pulverized coal in power plant service indicates that there is no difficulty in operating under these load conditions at the 85 per cent efficiency we have used for the basis of our calculations, which, as shown in Column 2, is equivalent to 16,250 B. t. u. per kw-hr. or 1¼ lb. of coal, containing 13,000 B. t. u.

In the appendix there is a record of some pulverized-coal-fired boiler tests which show a higher combined efficiency than we have assumed.

The final conclusions are:

(a) It will cost a great deal less money to equip and use pulverized coal in power plants in order to obtain the highest efficiency and the lowest operating costs than it would to use high pressure of 400 lb. and high superheat of 700 deg. final.

(b) That lower B. t. u. per kw-hr. and higher overall thermal efficiency will be obtained by substituting pulverized coal firing in lieu of any other known method using the moderate high pressure and superheat in common practise today, compared with higher pressures and temperatures.

(c) That the benefits accruing from the net difference in station water rate between the present practise as to pressure and temperatures and the higher pressures and temperatures are comparatively small and do not warrant the excessive additional first cost and yearly fixed charges for the higher pressures and superheat.

(d) That the cost per short ton of coal handled and burned by stokers in the 250-lb. pressure plant (exclusive of the cost of the coal) will be 52 cents and with pulverized coal 58 cents. For the 400-lb. pressure plant this cost would be increased to 95 cents per ton with stokers, which increase is due principally to the additional fixed charges over the 250-lb pressure plant.

Appendix

Tests of Pulverized Coal Fired Boilers Made in Accordance with the Standard A. S. M. E. Boiler Code

The equipment consists of a 1306-h. p. four-pass horizontal water tube Edgemoor boiler with 4-in. Fuller feeders and 4-in. flared type Fuller burners, located in a horizontal position, all as shown in the accompanying illustration.

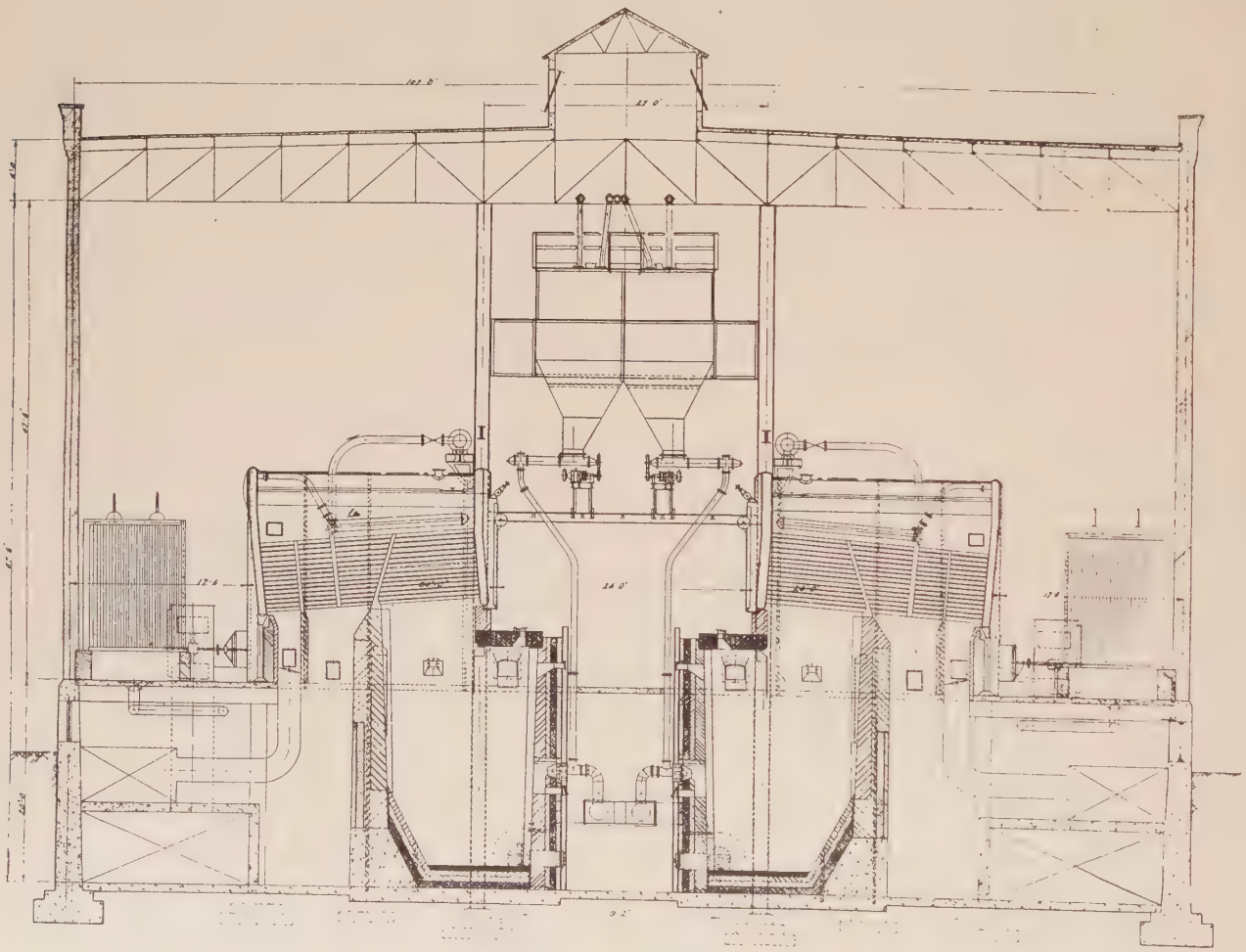


Fig. 1—Cross-Sectional View of Two 1308-H.P. Edgemoor Boilers
Arranged for burning pulverized Illinois coal.

The furnace conditions were most excellent and did not result in the formation of any slag. The furnace was not cleaned out during the time these two tests were run. There were but a few hours time between the finishing of No. 3 test of 48 hours and No. 4 test

of 48 hours. The boiler was kept on the main steam header and no special efforts were made to obtain high efficiency. The boiler tubes had not been turbined for sometime before the tests were conducted, neither had the outside of the tubes been washed out except as they were blown every day with soot blowers.

DATA AND RESULTS OF EVAPORATIVE TESTS NOS. 3 AND 4

1. Test of Edgemoor Boiler No. 1.
   To determine efficiency of boiler furnace and superheater.
   Test conducted by Fred. Darnbrook and A. Hoffman
   Ralph Galt and R. A. Kleppinger.
2. Edgemoor watertube boiler No. 1.
3. Powdered coal furnace.
4. Combustion space 9057 cubic feet.
5. 13057 sq. ft. water heating surface.
6. superheating surface.
7. total heating surface.
8. Date—Boiler Test No. 3 First half—June 30th & July 1st, 1921.
   Second half—July 1st and 2nd.
   Boiler Test No. 4 First half—July 5th and 6th.
   Second half—July 6th and 7th.
9. Duration—Boiler Test No. 3.
   First Half —24 hr. 53 min.
   Second Half—23 hr. 25 min.
   Average —48 hr. 8 min.
   Boiler Test No. 4.
   First Half —24 hr. 5 min.
   Second Half—23 hr. 45 min.
   Average —47 hr. 50 min.
10. Illinois coal powdered.

BOILER TEST NO. 3
HEAT BALANCE BASED ON DRY COAL

	First half		Second half		Average
	B. t. u.	Per Cent	B. t. u.	Per Cent	Per Cent
A. Heat absorbed by boiler	9732	81.7	10062	84.2	82.95
B. Loss due to evaporation H_2O in coal	61	.5	46	.38	.44
C. Loss due to heat carried by steam formed by the burning of hydrogen	443	3.7	398	3.33	3.51
D. Loss due to heat carried away in dry flue gases	1040	8.7	1108	9.27	8.99
E. Loss due to radiation and unaccounted for losses	640	5.4	336	2.82	4.11
	11916	100.0	11950	100.00	100.00

ULTIMATE ANALYSIS OF COAL

	First half	Second half
Carbon	68.40	68.21
Hydrogen	4.17	4.07
Nitrogen	1.37	1.26
Sulphur	4.00	3.91
Oxygen	9.30	9.37
Ash	12.76	13.18
B. t. u. Dry Coal	11916	11950

BOILER TESTS NO. 3 AND 4

	Test No. 3			Test No. 4		
Average Temperature and Pressures	1st half 24 hr. 53 min.	2nd half 23 hr. 25 min.	Average 48 hr. 8 min.	1st half 24 hr. 5 min.	2nd half 23.75 hrs.	Average 47 hr. 50 min.
11. Steam pressure by gage, lb. per sq. in.	263.46	264.2	263.8	267	266.7	267
a. Aneroid barometer				29.32	29.31	29.31
12. Temperature of superheated steam, deg. fahr.	280.34	584.7	582.5	600.8	596.1	598.4
a. Normal temperature of saturated steam, deg. fahr.	411	411	411	411.4	411.4	411.4
13. Temperature of feed water entering boiler, deg. fahr.	198.7	203	200.7	210.3	213.2	211.6
a. Temp. of feed water entering economizer, deg. fahr.	131	132.3	131.6	126.6	130.5	128.5
b. Increase of temperature due to economizer, deg. fahr.	67.7	70.7	69.1	83.7	82.7	83.2
14. Temperature of escaping gases,						
a. Temperature of gas below fourth pass, deg. fahr.	468	470	469	512	526	518.7
b. Temperature of gas entering economizer, " "	436	436	436	464	464	464
c. Temperature of gas leaving economizers, " "	220	240	230	259	268	263.3
d. Decrease of temperature due to economizer, deg. fahr.	216	196	206	205	196	200.5
15. Force of draft between damper and boiler,						
a. Draft in first pass, in. of water	0.02	0.0185	0.019	0.0625	0.055	0.058
b. Draft in fourth pass, in. of water	0.46	0.477	0.468	1.057	1.16	1.108
c. Draft entering economizer, in. of water	0.503	0.536	0.529	1.270	1.29	1.28
d. Draft leaving economizer, in. of water	0.706	0.777	0.741	1.908	1.94	1.93
16. State of weather,						
a. Temperature of external air, deg. fahr.	81	81	81	82	82	82
b. Temperature of air entering ash pit, deg. fahr.				121	121	121
c. Relative humidity of air entering ash pit,						
d. Room temperature, deg. fahr.			93	196	196	196
e. Temp. Feeder platform, deg. fahr.				110	108	109
Quality of Steam						
17. Number of degrees superheat, deg. fahr.	169.34	173.7	171.5	189.4	184.7	187.1
18. Factor for correction for quality of steam						
Total Quantities						
19. Total weight of coal as fired, lb.	157022	144978	302000	231352	220699	452051
20. Percentage of moisture in coal as fired, per cent	5.124	4.2	4.66	3.85	4.05	3.95
21. Total weight of dry coal, lb.	148975	138889	287864	222445	211760	434445
22. Ash, clinkers and refuse, (dry) per cent	13.137	13.395	13266	13.567	13.337	13.453
a. Withdrawn from furnace and ash pit,						
b. Withdrawn from flues, tubes and combustion space						
c. Blown away with gases						
d. Total						
23. Total combustible burned, lb.	129404	120278	249682	192255	183517	375782
24. Per cent of ash and refuse, based on dry coal, per cent	13.137	13.395	13.266	13.567	13.337	13.453
25. Total water fed to boilers, lb.	1278338	1232625	2509673	1908243	1870209	3787452

BOILER TESTS NO. 3 AND 4—*Continued*

Average Temperature and Pressures	Test No. 3			Test No. 4		
	1st half	2nd half	Average	1st half	2nd half	Average
	24 hr. 53 min.	23 hr. 25 min.	48 hr. 8 min.	24 hr. 5 min.	23.75 hrs.	47 hr. 50 min.
26. Total water evaporated, lb	1278678	1232625	2509673	1908243	1879209	3787452
27. Factor of evaporation, based on temperature of feed water entering boiler	1494135	1440938	2955073	2229209	2185332	4414541
a. Total equiv. evap. from and at 212 deg. fahr., lb	1.1685	1.169	1.1687	1.1682	1.1629	1.1655
28. Factor of evaporation, based on temperature of feed water entering economizer	1.2395	1.24	1.24	1.2545	1.2481	1.2513
a. Total equivalent evaporation from and at 212 deg. fahr., lb	1584921	1528455	3113376	2393890	2345440	4739330
Hourly Quantities and Rates						
29. Dry coal per hour, lb	5971	5973	5972	9080	8916	8998
30. Coal as received, per hour, lb	6293	6235	6274	9443	9292	9368
31. Water evaporated per hour, lb	51387	52982	52140	77887	79124	78495
32. Equivalent evaporation per hour, from and at 212 deg. fahr., lb.	60045	61934	61282	90988	92013	91492
33. Equivalent evaporation per hour, from and at 212 deg. fahr., per square foot of heating surface, lb	4.59	4.74		6.96	7.05	7.00
Capacity						
34. Evaporation per hour from and at 212 deg. fahr., lb	60045	61934	60936	90988	92013	91492
a. Boiler horse power developed, h. p	1740	1795	1766	2637	2667	2651
35. Rated capacity per hour from and at 212 deg. fahr., lb	45057	45057	45057			
a. Rated boiler horse power, h. p	1306					
36. Percentage of rated capacity developed, per cent	131.2	137.4	135.2	201.9	204.2	203.0
a. Flow meter, indicating h. p	1332					
Economy						
37. Water fed per pound of coal as fired, lb	8.143	8.5	8.31	8.248	8.51	8.3746
38. Water fed per lb. of dry coal, lb	8.51	8.87	8.71	8.58	8.874	8.728
39. Equivalent evaporation from and at 212 deg. fahr. per lb. of dry coal as fired, lb	9.515	9.93	9.7	9.63	9.90	9.762
40. Equivalent evaporation from and at 212 deg. fahr. per lb. of dry coal, lb	10.029	10.37	10.18	10.02	10.319	10.167
41. Equivalent evaporation from and at 212 deg. fahr. per lb. of combustible, lb	11.546	11.97	11.75	11.594	11.908	11.748
Efficiency						
42. Calorific value of 1 lb. of coal as fired, per analysis, B. t. u	11310	11449	11380	11465	11581	11522
43. Calorific value of 1 lb. of dry coal, per analysis, B. t. u	11916	11950	11932	11924	12070	11995
44. Calorific value of 1 lb. of combustible, B. t. u	13720	13799	13762	13782	13927	13853
45. Total heat absorbed by boiler,						
a. Total heat in steam, B. t. u	1302	1304	1303	1312	1309.7	1310.86
b. Total heat absorbed per lb. water fed to boiler, B. t. u	1135.3	1133	1134.3	1133.7	1128.5	1131.2
c. Total heat absorbed per lb. water fed to economizer, B. t. u	1203	1204	1203.4	1217.4	1211.2	1214.2
46. Efficiency of boiler, furnace and superheater, based on coal as received, per cent	81.7	84.1	82.8	81.56	82.92	82.23
47. Efficiency of boiler, furnace and superheater, based on combustible, per cent	81.66	84.1	82.8	81.62	82.97	82.19
48. Efficiency of boiler, furnace, superheater and economizer, based on coal as received, per cent	86.6	89.3	87.9	87.5	89.001	88.38
Gas Analysis—by Volume						
49. Fourth pass,						
a. Carbon dioxide	14.03	13.4	13.7	13.73	13.58	13.655
b. Oxygen	4.76	5.475	5.11	5.355	5.48	5.417
c. Carbon monoxide	0.013	0.00	0.00	0.041	0.0014	0.0214
d. Nitrogen (by difference)				80.874	80.8386	80.85
50. Economizer Inlet,						
a. Carbon dioxide				11.57	11.47	11.52
51. Economizer Outlet,						
a. Carbon dioxide				10.10	10.23	10.16
Analysis of Coal						
52. Moisture, per cent	5.125	4.2	4.55	3.85	4.05	3.95
Ash, per cent	13.137	13.395	13.255	13.567	13.337	13.454
B. t. u. per lb. of dry coal, B. t. u	11916	11950	11932	11924	12070	11995
B. t. u. per lb. of coal as received, B. t. u	11310	11440	11380	11465	11581	11522
Sulphur, per cent (separately determined)	4.23	3.81	4.03	3.997	3.422	3.709
Additional Data						
53. Rev. per min. feeder screws, No. 1 West	114	115	115	160	160	160
No. 2	99	96	98	160	138.7	149.3
No. 3	108	117	113	145	142	143.5
No. 4, East	121	117	119	158	165	161.5
54. Rev. per min. economizer fan	119	146		279	278	278.5

Triple Harmonics in Transformers

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Review of the Subject.—*Although the prolbem of higher harmonics in the electrical circuits of transformers is a generation old and the solution has been given by a number of eminent engineers, still hardly a week passes in a department specializing on the manufacture of transformers that an instance does not appear of the lack of comprehension of the relations involved. If the problem were entirely confined to the realms of the manufacturing specialists, it might well be passed over and taken care of by local educational work. But the troubles which arise from time to time in the practise of transmission and distribution of electrical energy on polyphase circuits due entirely to the method of connection of the three phases of polyphase apparatus warrants a review of the subject in a simple form.*

What are the troubles which may arise in transmission practise? The harmonics may, first set up potential strains in the transformer coils; second, raise the voltage of the line; third, burn out incandescent lamps; fourth, change the ratio of transformation of voltage under low-load conditions from its proper value as determined by the ratio of the number of turns on the primary coil to the number of turns on the secondary coil; fifth, produce a triple harmonic current in the neutral connection to ground; sixth, induce a distracting hum in telephone receivers connected to parallel telephone circuits; seventh, produce abnormally high voltages and large currents in odd places on the circuits due to a resonance with a natural frequency of the circuit; and so on.

To get at the basic effect which causes these triple-harmonic troubles the magnetization current of a single-phase transformer may be considered. If the applied potential at the terminals of the transformer is the familiar smooth sine wave it is well-known that the magnetizing current is not a sine wave but is a smooth distorted wave. On the other hand, if a pure sine wave of current is forced through the primary there appears on both the primary and the secondary a smooth but distorted wave of potential. It must be one or the other.

It often helps the understanding and avoids possible confusion to point out a resemblance which is actually a different phenomenon. Instead of finding by oscillographic tests that a current wave is smooth, it may be somewhat saw-toothed. This occurs when a generator supplies current to a condenser, such as an unloaded overhead line or electric cable. A generator usually has either twelve teeth on the armature per pair of poles (that is to say per cycle) or eighteen teeth. If there are twelve teeth, the nearest odd number for the necessarily odd harmonic is either eleven or thirteen. Likewise, if there are eighteen teeth there will be found either seventeen or nineteen saw-teeth or ripples on the main wave. These variations from a sine wave are known as teeth harmonics which entirely distinguish them from the distortions of the sine wave by the effect of variable permeability of the iron. The teeth harmonics, if they exist, are so numerous they can be counted on the oscillographic wave. The permeability harmonics being lower and nearer the first harmonic distort the general shape of the wave without making it visibly evident whether the third, fifth, or seventh is the cause.

In passing—the even number of harmonics cannot exist continually in the generator wave of either current or voltage because an even number harmonic would make the positive half of the wave different from the negative half of the wave. The simplest proof, without mathematics, is to draw a sine wave, superpose on it a sine wave of twice the frequency, and combine the two to form a third wave.

The distortion of the wave of magnetizing current away from a sine wave may be explained to the mathematically inclined by reference to Fourier's Theorem—a long involved trigonometric equation. It is more evident to put the analysis in words. The distorted current wave is apparently scrambled sine waves. Unscrambled, the elementary sine waves are found in perfect order. There is primarily the first harmonic or fundamental frequency (the generator frequency). This first harmonic is almost as large as the original wave. Since there can be no even harmonics, the next harmonic, somewhat smaller in amplitude, is the third—three times the frequency of the generator. Then comes the fifth harmonic, five times the frequency of the generator and very much smaller than the third. There is also a still smaller yet appreciable seventh harmonic, seven times the generator frequency.

But all of this analysis is like describing an egg without saying anything about the bird that produced it. What caused all these sine waves of odd frequencies? It was not the eddy-current in the laminated iron. It was not the hysteresis loss in the iron. It did not come from any electrical effect in either the primary or the secondary electrical circuits. With this narrowing down of the cause, it may be definitely located in an intrinsic characteristic of magnetic iron. At different degrees of magnetizing force (ampere-turns) the molecular magnets add different degrees of magnetism to the iron core. If the distorted wave of magnetism is the egg, this permeability is the hen that produced it.

It may also add to clarification to point out a discontinuity or missing link. Magnetization curves are usually given in coordinate graphs with current or ampere turns as the abscissas and magnetism as the ordinates. On the other hand, the magnetizing current of the transformer is usually given with an entirely different factor as abscissas, namely the time, and the ordinates as a near relative to magnetism, namely the voltage. The missing link between these two forms of graphic expression must be supplied.

In the following treatment of this subject a coordination of the factors involved is obtained by starting with a fully analyzed wave of magnetization and synthetically constructing, step by step, the shape that the artificial permeability curve of the iron would have to assume to permit, first, the production of the first harmonic sine wave of magnetizing current from an applied sine wave of electromotive force and then the effect of the other harmonics. Fig. 5 shows the first harmonic (the larger wave), and Fig. 5A the corresponding artificial permeability curve, the straight line O M. Next the artificial permeability curve is synthetically constructed on the basis that the first harmonic and the third harmonic of Fig. 5 are combined. They produce the artificial permeability curve OA′ B P of Fig. 5A which is nearer the real permeability curve than a straight line O M. Next, the first harmonic and the fifth harmonic of Fig. 6 are combined to form the permeability curve O A′ B C′ F of Fig. 6A. It is readily seen that this curve does not resemble the well-known permeability curve which is shown in Curve 1 of Fig. 7. However, if in the next step the first, third, and fifth harmonics are combined and a permeability curve is constructed from the three of them, which is Curve 2 of Fig. 7, this curve approaches closely to the real permeability curve (Curve 1.) The difference between this last synthetic permeability curve and the real permeability curve is due to the fact that there is a seventh harmonic of current of small value necessary to correct the difference. Even still smaller values of higher harmonics may be necessary for still greater accuracy.

The effects that may be obtained in Y connections, delta connections, and various combinations thereof are discussed in detail. An executive might well sum up the whole subject, without going into detail, by asking an engineer the simple question: Have you given a circuit for the circulation of the third harmonic? If not, can you be sure the third harmonic will not cause some trouble?

Lecture delivered before the Schenectady Section of the A. I. E. E., October 21, 1921.

ALTHOUGH this problem is old and was solved a long time ago, I believe that a review of its salient features will prove interesting and useful.

Three single-phase transformers were connected Y primary, diametrical secondary as shown in Fig. 1. Each transformer had a 2300-volt primary winding and

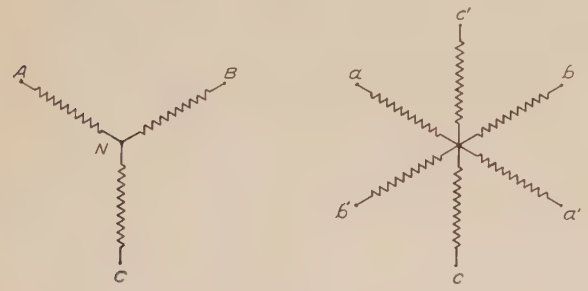


FIG. 1—TRANSFORMER CONNECTIONS

a 230-volt secondary winding; the ratio of transformation was therefore 10 to 1. Incidentally each transformer had a capacity of 25 kv-a.

Four thousand volts three-phase were applied between $A\,B$, $B\,C$ and $C\,A$. Since $\frac{4000}{\sqrt{3}} = 2300$ it was supposed that the proper voltage (2300 volts) was applied to each transformer $A\,N$, $B\,N$ and $C\,N$. Since the ratio of transformation was 10 to 1, across each secondary $a\,a'$, $b\,b'$ and $c\,c'$ a voltage of $\frac{2300}{10}$ or

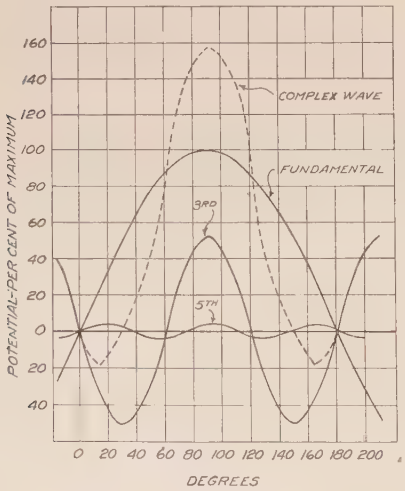


FIG. 2—COMPLEX WAVE

Made up of three sine waves: The fundamental or first harmonic, a smaller third harmonic, and a still smaller fifth harmonic.

230 volts would have been expected. However, when the voltage across $a\,a'$, $b\,b'$ and $c\,c'$ was measured with a voltmeter it was found to be 260 volts.

The ratio between the number of primary and secondary turns was checked and found to be correct, the wave shape of the voltage applied to $A\,B$, $B\,C$ and $C\,A$ was also checked and found to be practically a sine wave. When an oscillographic record of the secondary voltage $a\,a'$ was taken, this voltage was found to be greatly distorted. This oscillographic record is reproduced in Fig. 2 and is marked "complex." The wave was analyzed and resolved into its components, *i. e.*, the fundamental, the harmonic third and the fifth harmonic.

The relative values of these components are shown in the following table:

	Effective Value			Maximum Value		
Fundamental	100%	230	volts	100%	324	volts
Third	51.6%	118.7	"	51.6%	167	"
Fifth	3.4%	7.8	"	3.4%	11	"
Complex	113%	260	"	155%	502	"

This table, which shows the voltage across each secondary winding of the transformers, and therefore across each primary winding of the transformers, is very instructive and shows the following results.

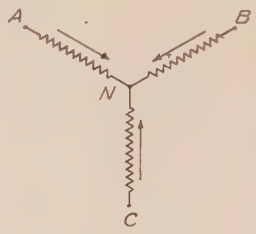


FIG. 3

1. Although a sine wave is applied between lines, the leg voltage is not a sine wave, and therefore it cannot be calculated by dividing the line voltage by the square root of 3.

2. The distortion is due mainly to a triple frequency component of the voltage with the addition of a small fifth harmonic.

3. The effective value of the secondary voltage was raised from 230 volts to 260 volts or 13 per cent. Therefore, the leg voltage of the primary circuit was also raised from 2300 volts effective to 2600 volts effective or again 13 per cent.

When the voltmeter was connected across $a\,a'$ it did show this effective value, *i. e.*, 260 volts. The effective values of sine waves of different frequencies add as if they were in quadrature, that is to say, the effective value of the complex wave is equal to the square root of the sum of the squares of the fundamental of the third and of the fifth harmonic.

4. The maximum values, however, add directly, so that while the effective value of the distorted wave is only 13 per cent higher than the effective value of the fundamental, the maximum value of the distorted wave is 55 per cent higher than the maximum value of the fundamental. It is this maximum value that controls the dielectric stress on the insulation of the transformers.

5. It must be noted that the triple frequency components of the leg voltages are in phase with one another. In fact referring to Fig. 3 the leg voltages $A\,N$, $B\,N$, $C\,N$ are 120 degrees apart so far as their fundamental components of normal frequency are concerned, but the triple harmonics of these voltages are 3×120 degrees or 360 degrees apart, in other words, they are in phase. The arrows of Fig. 3 show the directions of these triple frequency components which, we repeat, are in phase and equal in value. Now we see that from A to B the triple frequency component of the leg $A\,N$ is equal and opposite to the triple frequency component of the leg $B\,N$ so that while the triple harmonic, amounting to 51.6 per cent of the fundamental distorts the voltage $A\,N$ and an identical triple harmonic distorts the voltage $B\,N$, no triple frequency distortions will appear across $A\,B$ and likewise not across $B\,C$ and $C\,A$. Hence the line voltage has no triple frequency distortion.

The small fifth harmonic component will appear across the line wires, as it was present in the wave of applied voltage or it was introduced by "drops" due to the fifth harmonic component of the exciting current. Let us remember that the triple frequency components appear in the leg voltages but not across the lines, while the components of other frequencies, including the fundamental, appear both across the legs and across lines of the Y.

6. Since the triple frequency components of the leg voltages $A\,N$, $B\,N$ and $C\,N$ are equal in value and in phase it follows that the point N has a difference of potential from the geometrical neutral of the system equal to the triple frequency component of each leg voltage. If the voltages $A\,B$, $B\,C$ and $C\,A$ are properly balanced so that the geometrical neutral point of the system constituted by them is at ground potential, the neutral N of the windings will have a voltage to ground equal to the triple frequency distortion of each leg, *i. e.* in this case equal to 51.6 per cent of the fundamental voltage of each leg, or approximately 30 per cent of the line voltage.

7. If the point N is grounded and therefore at zero potential, then the points A, B and C will have a difference of potential to ground equal to the triple frequency component of the leg voltage in addition to the difference of potential to ground due to the fundamental voltage of normal frequency. This means that the three terminals A, B and C will rise above ground potential and fall simultaneously at triple frequency.

The natural question now arises as to why the main source of distortion is the third harmonic. As we have seen, the third harmonic assumes peculiar characteristics in connection with three-phase systems.

In order to understand why the main distortions in the case we have considered is due to a triple frequency wave, let us study the phenomena connected with the excitation of a coil, whose ohmic resistance we neglect when a sine wave of voltage is applied to it. If the magnetic flux goes through air or, in general, through a medium of constant permeability and free from losses, the flux would be a sine wave in quadrature with the voltage, and the current necessary to produce the flux will also be a sine wave in phase with the flux. Conditions are quite different if the coil contains an iron core. Let us take one of the 25-kv-a. transformers which we have considered before and excite it at normal voltage, this voltage being practically a sine wave.

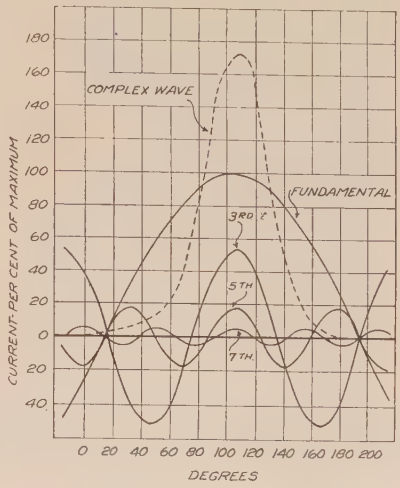


FIG. 4—COMPLEX WAVE

Made up of four sine waves consisting of the fundamental or first harmonic, a smaller third harmonic, a still smaller fifth harmonic, and a much smaller seventh harmonic.

Fig. 4 shows the magnetizing current. The total current flowing through the exciting coil has a component which is a sine wave in phase with the voltage and which supplies the losses. After deducting this power component from the total current, the reactive current which produces the flux is shown in Fig. 4.

This reactive current contains a fundamental, a third, a fifth and a seventh harmonic, the value of each component being given in the following table:

	Effective	Maximum
Fundamental.....	100%	100%
Third.....	52.7%	52.7%
Fifth.....	18.5%	18.5%
Seventh.....	5.1%	5.1%
Complex.....	114.5%	175%

We see again the difference between the effective values and the maximum values which we have noted above. In this case the sum of the maxima of all the components should give a maximum value of the complex wave equal to 176.3 per cent, but since the maxima are not all in phase the maximum of the complex wave is reduced to 175 per cent.

Now if we connect the three transformers in Y with diametrical secondaries we find that the triple frequency component of the current cannot flow. We have seen

that the triple frequency components of the leg voltages are in phase with one another; this applies also to the currents and therefore if we represent with arrows the direction of the third harmonics of current through the three legs of the Y, these arrows will all point toward the neutral. (See Fig. 3.) This means that the third harmonics of magnetizing current cannot flow. It follows that the flux in each of three transformers

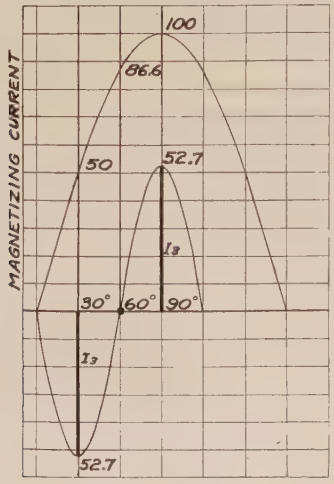


FIG. 5—MAGNETIZING CURRENT

Represented by two elements—the fundamental or first harmonic shown with a peak of 100 and the third harmonic with a peak of 52.7. The third harmonic is 180 deg. out of phase with the first harmonic.

cannot be a sine flux because a triple frequency component of the magnetizing current is necessary to give a sine flux and this triple frequency current cannot flow.

Since the flux in each transformer cannot be sinusoidal, the voltage across each leg of the Y cannot be sinusoidal, in fact, as we have seen before, it is distorted by a triple frequency component.

Summing up, the distortion of the leg voltage which has been under discussion is caused by the absence of the triple frequency component of the magnetizing current in the Y. The next question is, why a triple frequency current is necessary to produce a sine flux in an iron core.

To be sure, a fifth and seventh harmonic and in some cases other harmonics of higher frequency are necessary to magnetize the iron core, but the third harmonic is the most prominent and furthermore, as we noted above, it gives origin to special phenomena in three-phase systems.

It is evident that the change in permeability of the iron during a cycle is responsible for the distortion of the current. Since we have assumed no losses in the core and we have eliminated the power component of the current these losses are not responsible for the distortion of the current.

If the magnetizing current were a sine wave and this sine wave of current could produce a sine wave of flux, the so-called saturation curve of the magnetic circuit would be a straight line as shown by $O\,M$ in Fig. 5A. That is to say, at any point the flux would be proportional to the current and if the flux is a sine wave the current would also be a sine wave. As the current increases from 0 to 100 per cent during a quarter of a cycle the flux density in the core increases in our special case from 0 to 100 kilolines per square inch and when the current decreases and reverses the flux follows it.

The tangent of the angle that the line $O\,M$ makes with the horizontal gives the ratio between the flux density and the ampere turns and is proportional to the *average* permeability of the magnetic circuit, which permeability we have assumed constant.

In order to ascertain the reason for the presence of a triple frequency component of the magnetizing current, let us investigate the relation between the saturation curve of the magnetic circuit and the triple frequency component of the magnetizing current. In other

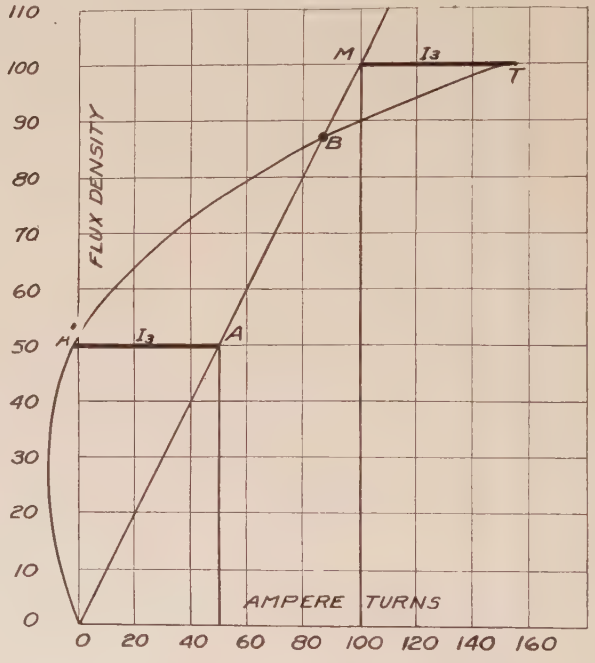


FIG. 5A—TWO MAGNETIZATION CURVES

A straight line, $O\,A\,M$, is the synthetic magnetization curve which corresponds to the fundamental sine wave of Fig. 5. The curve $O\,A'\,B\,T$ is the synthetic magnetization curve on the assumption that the magnetizing current is the third harmonic in addition to the first harmonic as shown in Fig. 5. Neither of these synthetic magnetization curves agrees with the actual magnetization curve of the transformer iron. However, the magnetization curve $O\,A'\,B\,T$, constructed with the addition of the third harmonic, is nearer to the actual magnetization curve than the one from the first harmonic.

words, let us take a magnetizing current composed of a fundamental and of a triple frequency component and see what saturation curve this magnetizing current would call for. By so doing we eliminate the influence of the other harmonics of the magnetizing current and concentrate on the relation between the triple frequency component of the magnetizing current and the saturation curve.

Fig. 5 shows the magnetizing current consisting of a

fundamental of 100 maximum value and triple frequency current of 52.7 per cent maximum value (this is the value of the triple frequency component shown in Fig. 4). The flux is a sine wave proportional to the fundamental of the magnetizing current and its maximum value is 100 kilolines per square inch.

At zero degrees the flux is zero, the fundamental current is zero, the triple frequency current is zero and we have the point zero of the saturation curve.

At 30 deg. the flux is sin 30 deg. $\times$ 100 = 50, and the fundamental current is also sin 30 deg. $\times$ 100 = 50; that is to say, if the fundamental existed alone we would have the point A of line $O\,M$. But at 30 deg. the triple frequency component has a maximum negative value equal to 52.7, therefore, the presence of the third harmonic shifts the saturation curve from A to A'.

At 60 deg. the flux is sin 60 deg. $\times$ 100 = 86.6, likewise the fundamental current is sin 60 deg. $\times$ 100 = 86.6, and the triple frequency component is zero. At this point the third harmonic of the magnetizing current has no influence and we have the point B on the line $O\,M$.

At 90 deg. the flux and the fundamental current are 100. If the third harmonic of the current were not present we would get the point M. However, at 90 deg. the third harmonic of the magnetizing current has a maximum value of 52.7 and, therefore, the saturation curve is shifted from the point M to the point T.

By using the same method at different angles we can plot the saturation curve $O\,A'\,B\,T$ which calls for a magnetizing current consisting of a fundamental and of a 52.7 per cent triple frequency magnetizing current. The presence of the third harmonic of the magnetizing current is due to a distortion of the saturation curve from a straight line $O\,M$ to the curve $O\,A'\,B\,T$. If this curve $O\,A'\,B\,T$ were the actual saturation curve of the magnetic circuit the magnetizing current would consist of the fundamental and of the third harmonic as shown in Fig. 5 and no other harmonics would be present. However, we see at once that $O\,A'\,B\,T$ is not a normal saturation curve given by iron circuits, because

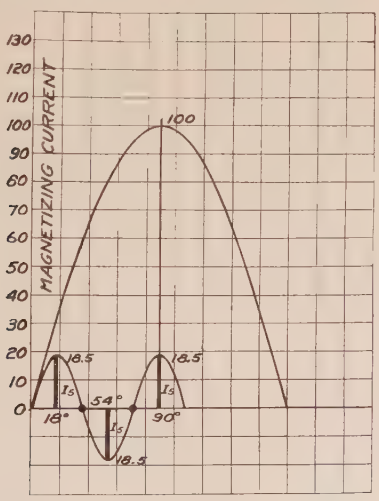


Fig. 6—Magnetizing Current

Represented by two elements—the fundamental or first harmonic shown with a peak of 100 and the fifth harmonic starting in phase with the first harmonic and having a peak represented by 18 per cent.

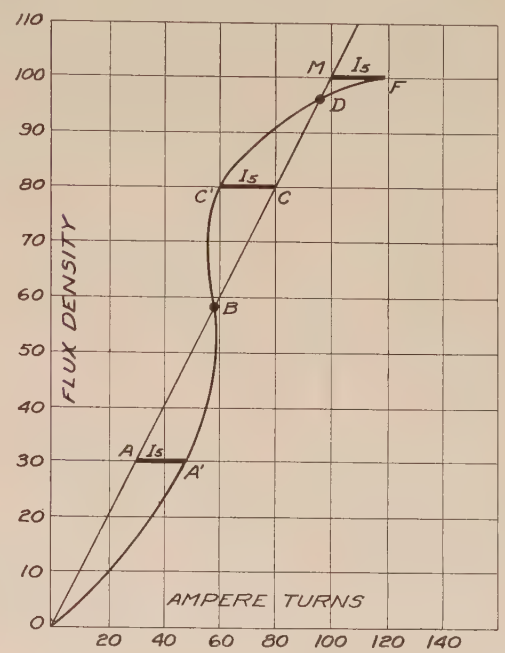


Fig. 6a—Two Magnetization Curves

A straight line, $O\,A\,M$, is the synthetic magnetization curve which corresponds to the fundamental sine wave of Fig. 6. The curve $O\,A'\,B\,C'\,D\,F$ is the synthetic magnetization curve on the assumption that the magnetizing current is a combination of the first and fifth harmonics, as given in Fig. 6.

the lower part of the curve is excessively distorted while the upper part, around 90 deg., is not distorted enough; the third harmonic of the magnetizing current is not sufficient; other harmonics must occur which decrease the distortion at the lower part of the saturation curve and increase it at the maximum point. We see, however, that the general shape of the curve $O\,A'\,B\,T$ coincides somewhat with the general shape of the saturation curve of an iron circuit. The third harmonic of the magnetizing current bends the straight line $O\,M$ into a curve which describes, so to speak, an alternation and a half on $O\,M$ taken as the axis, *i. e.* the third harmonic of the magnetizing current gives to the saturation curve the general character required by the iron circuit, the other harmonics contributing in minor details.

Passing now to the fifth harmonic let us find the relation between the fifth harmonic component of the magnetizing current and the saturation curve. In Fig. 6 we show a magnetizing current containing a fundamental whose maximum value is 100 and a fifth harmonic whose maximum value is 18.5 (this is the value of the fifth harmonic of Fig. 4). Following the same procedure as used in the case of the third harmonic let us plot the saturation curve which would call for a magnetizing current containing a fundamental

and the fifth harmonic. If the fundamental alone were existing, the saturation curve would be a straight line $O\,M$ as before. See Fig. 6A. Because the fifth harmonic exists, the points A, C and M are shifted respectively to A', C' and F. The values $A\,A'$, $C\,C'$ and $M\,F$ are the maximum value of the fifth harmonic of the magnetizing current and the points A, C and M are respectively at 18 deg, 54 deg and 90 deg.

The fifth harmonic of the magnetizing current does not offset the points B and D respectively at 36 deg. and 72 deg. where the fifth harmonic has zero value.

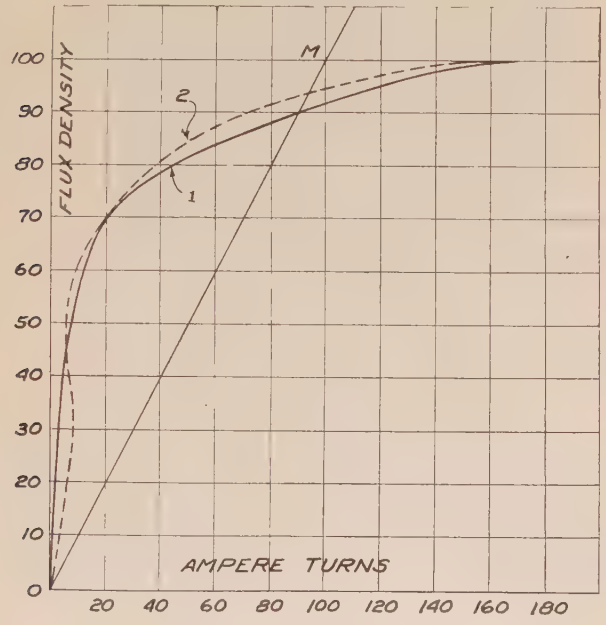


FIG. 7—THREE MAGNETIZATION CURVES

The straight line $O\,M$ is again the synthetic magnetization curve of the first harmonic. The magnetization curve 2 is a synthetic combination of the first, third and fifth harmonics, shown in Figs. 5 and 6. The magnetization curve 1 is the actual curve of the iron. The synthetic curve 2 differs from it very slightly, due mostly to the presence of the seventh harmonic.

The fifth harmonic component of the magnetizing current would be called for by a saturation curve $O\,A'\,B\,C'\,D\,F$ which makes, so to speak, $2\frac{1}{2}$ alternations on the straight line $O\,M$ taken as the axis. We see at once that the presence of the fifth harmonic of the magnetizing current does not give to the saturation curve of Fig. 6A the characteristic form of the saturation curve of iron circuits such as the third harmonic of the magnetizing current has produced in Fig. 5A. However, it corrects the distortion of the saturation curve at the lower part of the curve, which distortion the third harmonic had exaggerated, and it helps the third harmonic in further extending the saturation curve at the maximum point of 90 deg.

Likewise we could investigate the influence of the seventh harmonic of the magnetizing current which would give a saturation curve making $3\frac{1}{2}$ alternations on the line $O\,M$ taken as the axis. But this we omit.

Now let us combine the saturation curve of Fig. 5A due to the third harmonic with the saturation curve of Fig. 6A due to the fifth harmonic and we have curve 2 of Fig. 7. Curve 1 of Fig. 7 is the saturation curve of the iron circuit, and the difference between curve 2 and curve 1 is made up by the higher harmonics of the magnetizing current which we have not considered. We see, however, that these high harmonics are of minor importance and that the third harmonic is the principal factor in adapting the magnetizing current to the saturation curve.

We are able to recapitulate the situation we have reviewed as follows:

1. The magnetization of a single-phase transformer excited by a sine wave e. m. f. and, therefore, by a sine wave flux, requires that the magnetizing current be distorted to accommodate the varying permeability of the iron circuit. Because of the peculiar shape of the saturation curve of iron the distortion of the magnetizing current is due mainly to a large third harmonic.

2. The third harmonic of the magnetizing current cannot flow in a Y-connected three-phase system of transformers, therefore if no other provision is made the flux of each leg of the three-phase Y-connected system of transformers cannot be a sine flux, and therefore the leg voltage is not a sine wave.

3. The distortion of this leg voltage is a third harmonic because the flux contains a third harmonic component which would have been eliminated if the magnetizing current could have had its proper triple frequency component.

The presence of a third harmonic component of the leg voltage is objectionable because it increases the stress on the insulation by giving a higher maximum

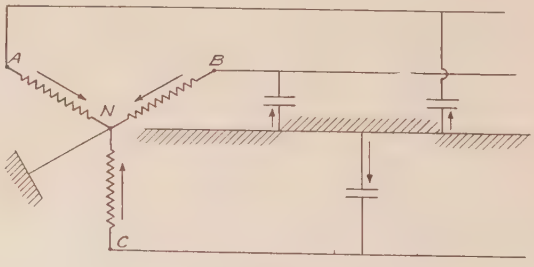


FIG. 8

value of the voltage wave, and because, when the neutral is grounded, the line wires have a triple frequency voltage to ground, causing dangerous induction to neighboring circuits as, for instance, telephone circuits. Another objection is that the triple frequency distortion of the voltage may be amplified by the line capacity. Referring to Fig. 8, $A\,N$, $B\,N$ and $C\,N$ are the windings of three transformers, the secondary windings being also connected Y and the neutral N being grounded. The triple frequency component of the magnetizing current which could not flow, as we have seen before, if the transformer were not connected to the line, finds it possible now to flow by returning through the ground and through the line capacitance

as shown by the arrows. Neglecting ohmic resistance and the ground resistance the impedance of the circuit through which the current flows is

$$2\pi f L - \frac{1}{2\pi f C}.$$

where L is the inductance of each winding of the transformer, C is the capacity of each line conductor to ground and f is three times the normal applied frequency. Several combinations may occur.

First, if C is very large as compared with L, $\frac{1}{2\pi f C}$ is practically zero and the line capacity offers a short circuit to the flow of the triple frequency magnetizing current which will, therefore, reach practically its full value so that the voltage distortion is eliminated. This explains why a comparatively small transformer connected to a large system, although its neutral is grounded, does not succeed in "wobbling" the conductors of the system at triple frequency to ground.

Second, if L is equal to C, then resonant conditions are reached with the possibility of the excessive voltages and currents that accompany resonance.

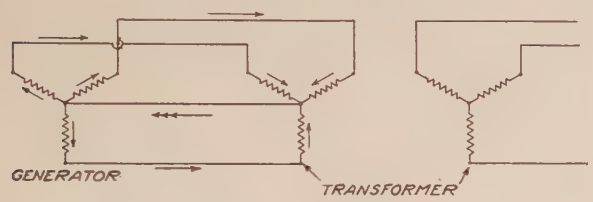


Fig. 9

Third, if C is small compared with L, then $\frac{1}{2\pi f C}$ is larger than $2\pi f L$ and the current flowing is a leading current. In case 1 the current was lagging and therefore magnetized the transformer and eliminated the triple frequency distortion of the leg voltage. In this case the current is leading and therefore it amplifies the triple frequency distortion of the voltage and dangerous values may be reached. In practise actual failures have occurred due to this cause.

It is therefore necessary to eliminate the triple frequency distortion of the leg voltage and this can be accomplished by comparatively simple means. Fig. 9 represents a transformer with both windings Y-connected and the generator also Y-connected, exciting the transformer. If no special provision is made the triple frequency component of the magnetizing current could not flow in the excited winding of the transformer and the leg voltage would be distorted with the possible dangers mentioned above. However, if the neutral of the excited winding of the transformer is connected to the neutral of the generator, then the triple frequency components of the magnetizing currents can flow as shown by the arrows and since these triple frequency components are in phase and equal in value, the current flowing through the neutral will have three times the value of the triple frequency current flowing through each leg. The same result would be obtained if the neutral of the transformer and the neutral of the generator were both grounded and the ground resistance were negligible. If the connection between the neutral

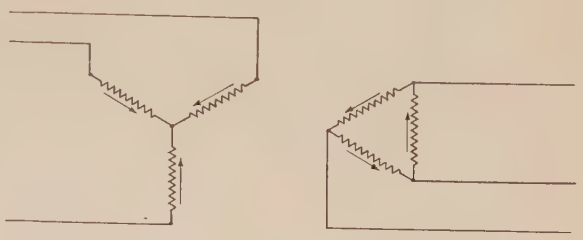


Fig. 10

has considerable resistance then the distortion of the leg voltage is not entirely eliminated but a triple frequency e. m. f. remains across each leg, this e. m.f. being of sufficient value to force the triple frequency currents through the neutral resistance.

Another method to prevent the triple frequency distortion of the leg voltage is to provide a delta winding in good mutual induction with the Y winding; this delta winding may be the secondary of the transformer or a tertiary winding. Fig. 10 shows the direction of the third harmonics of the magnetizing current in the primary Y, which third harmonics cannot flow. However, the third harmonics can flow in the delta because, again, they are in phase and equal in value so that they simply constitute a circulating current in the delta. Let us note that the direction of the arrows

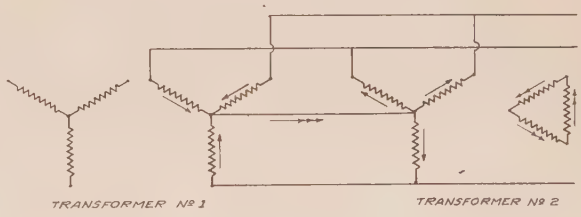


Fig. 11

in the delta is the same as the direction of the arrows in the Y, assuming that both are wound in the same direction. This is correct because the current flowing through the delta is a magnetizing current which supplies the triple frequency flux necessary to make a total sine wave flux in each leg, and therefore the current in the delta has exactly the same phase and value (taking into account the ratio transformation) that it would have had in the Y if it had been possible for it to flow in the Y. It is of interest to note that if the delta winding is open, then the triple frequency magnetizing current cannot flow and therefore each leg

voltage is distorted by a triple frequency component. This triple frequency distortion appears, of course, both across each leg of the primary *Y* and across each leg of the delta, which now is open, and since the three triple frequency components of the leg voltage are in phase and equal in value it follows that a voltmeter across the open delta will show a triple frequency e. m. f. equal in value to three times the triple frequency e. m. f. which distorts each phase.

An interesting case is shown in Fig. 11. Transformer No. 1 is *Y Y*-connected and, if alone, could be subjected to triple frequency voltage distortion because triple frequency magnetizing currents cannot flow. Transformer No. 2 is *Y*-delta-connected; its primary is in parallel with the primary of transformer No. 1 and its neutral is connected to the neutral of transformer No. 1. The triple frequency currents of transformer No. 1 directed toward the neutral are the magnetizing currents which can flow by returning through the neutral connection and through the windings of transformer No. 2. We see, however, that the triple frequency currents flowing through the *Y* of transformer No. 2 are opposite in direction to the currents which would properly magnetize the transformer. That is to say, these currents would not eliminate the third harmonic of the leg voltage but would amplify it. Transformer No. 2, however, has a secondary delta and the triple frequency currents can circulate through the secondary delta and eliminate the triple frequency voltage distortion. Fig. 11 shows that a triple frequency current of double intensity flows through the delta, in fact, a magnetizing triple frequency current flows through the delta and takes care of the magnetization of transformer No. 2, another triple frequency current flows through the delta and eliminates the demagnetization effect of the current flowing through the *Y*. This second current is, therefore, in the nature of a load current and is opposite in direction to the current flowing in the *Y* of transformer No. 2.

Summing up, transformers No. 1 and No. 2 which are supposed to be alike in their magnetic circuits are both free from triple frequency distortion because transformer No. 1 sends its triple frequency magnetizing current through the neutral and through the winding of transformer No. 2, and the delta of transformer No. 2 magnetizes transformer No. 2 and corrects the demagnetization produced by the third harmonic current of transformer No. 1. We can say that the delta of transformer No. 2 supplies the triple frequency magnetization for both transformer No. 1 and transformer No. 2. This action of a delta winding is worthy of consideration because the attempt of the secondary delta winding to supply the triple frequency magnetization to transformers connected in parallel to the primary side and which would otherwise have distorted voltage, may result in the delta winding being overloaded.

The distortion due to triple frequency harmonics of the voltage assumes an interesting aspect when a so-called core-type three-phase structure is used as shown in Fig. 12. The core has three legs and on each of these legs is wound one phase of the three-phase

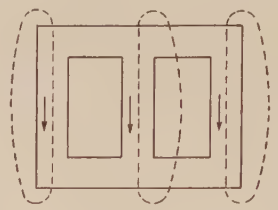


Fig. 12

circuit. Now, if three single-phase transformers are used or if a three-phase shell-type transformer is used, the latter being shown in Fig. 13, each phase has an independent magnetic circuit and the phenomena described above take place. However, in the three-phase core-type structure, shown in Fig. 12, conditions are different. The triple frequency components of the flux which are present when the triple frequency components of the magnetizing current cannot flow and which produce the distortion of the leg voltage, flow in the magnetic circuit as shown by the arrows. These triple frequency components of the flux are equal in value and in phase, therefore they can not flow entirely in the iron circuit but as shown by Fig. 12 they must return through air. In other words, the three-phase core shown in Fig. 12 is such that a very high reluctance is offered to the triple frequency components of the flux, whereas the components of fundamental frequency or of other frequencies flow entirely in the iron circuit and at each instant one leg has a flux equal and opposite to the resultant of the fluxes of the other two legs. It follows that if the core of Fig. 12 is wound with three windings connected in Y so that the triple frequency component of the magnetizing current cannot flow in the primary or in the secondary winding, a triple frequency flux will flow through the three legs of the core and return through air, but, because of the high

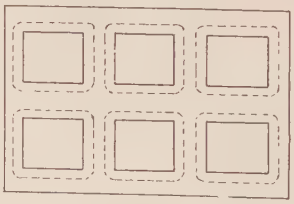


Fig. 13

reluctance presented to this flux the distortion that it produces in the leg voltage is comparatively small. In fact we have seen that the distorted leg voltage of systems consisting of three single-phase transformers is of the order of 50 per cent of the fundamental; this applies also to shell-type three-phase structures. However, in the core-type three-phase structures the leg voltage distortion is of the order of 5 per cent of the

fundamental. To eliminate this distortion the same means can be used as described above.

An interesting case occurs when a shell-type three-phase transformer, for instance, is connected in parallel with a core-type three-phase transformer. Both transformers are Y Y-connected and the neutrals of the primary Y's are connected as shown in Fig. 14. The shell-type transformer, if alone, would have a triple frequency component of the leg voltage equal to 50 per cent of the fundamental, while the core-type transformer, if alone, would have a triple frequency component of the leg voltage equal to 5 per cent of the fundamental. It is evident that the two transformers being connected in parallel with neutrals connected must have the same voltage across each leg, and therefore a current will flow, as shown by the arrows which will tend to equalize the voltages. Since these voltages differ in their triple frequency components the circulating current will be a triple frequency current and will flow in such a direction as to lower the triple

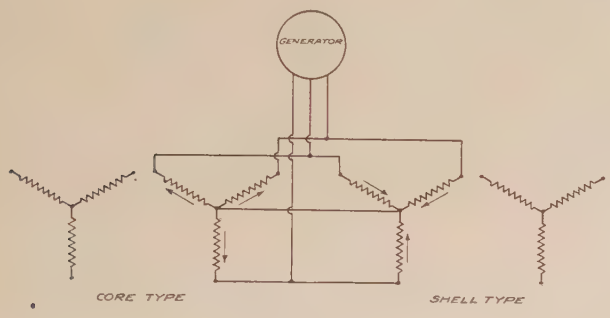


FIG. 14

frequency voltage of the shell type and to raise the triple frequency voltage of the core type. Because of the difference in the reluctance of the two magnetic circuits to triple frequency fluxes, the same current would produce in the shell type a triple frequency voltage equal to 50 per cent of the fundamental and in the core type a triple frequency voltage equal to 5 per cent of the fundamental. The circulating current will have evidently a value of 81.8 per cent of the current which would eliminate the distortion in either transformer. This 81.8 per cent current will decrease the distortion of the shell type from 50 per cent to 9.1 per cent and will raise the distortion of the core type from 5 per cent to 9.1 per cent. In other words the core-type transformer will act, similarly to a Y-delta transformer, to decrease the triple frequency distortion of the leg voltage.

Finally, it must be noted that a path to the triple frequency components of the magnetizing current may be afforded, under certain conditions, by the load of the transformer.

The first electric train was run March 20, 1922, on the Genoa-Modane route which is 272 kilometers in length, and the longest single electrification in Europe.

RESEARCH FROM THE BUSINESS VIEWPOINT*

The average manufacturer is inclined to think that all real progress comes from the factory, and that the only use for research men is to explain things after they have happened. Assuming research to have been "sold" with the aid of Mr. Skinner's suggestions,† what can we afford to spend on research, and how shall we compute the sum that we can afford to spend? Research may be divided into five classes, as suggested by Mr. A. P. M. Fleming of England. (1) Fundamental research in pure science, (2) Fundamental research in industrial science, (3) Public service research, (4) Research conducted by the works laboratory, and (5) Research conducted by the control laboratory.

Into the field of fundamental science, only the broader minded corporations will enter. Many regard it as unprofitable. It should be looked upon as an investment with deferred returns, and a small amount at least should be set aside for it by many corporations.

In the field of fundamental industrial science there are great possibilities. For example, only 4 per cent of available energy appears as useful illumination in the incandescent lamp. Obviously it is conceivable that a much larger percentage could be utilized. The difficulty is to find out a way to do it. Whatever sums of money are expended in fundamental industrial research, with the end in view of developing some new product, must be looked upon more or less in the light of a gamble. The chances of success rest upon many conditions which must be evaluated. Moreover the degree of success possible is an important determining element. For example, if lamps had reached 99 per cent of possible efficiency it is evident that only a very small expense to further improve the efficiency could be justified.

The primary function of the works laboratory is to reduce the cost of production, while that of the control laboratory is to insure the standard of quality in output. By public service research is meant the investigation of the uses in the hands of the consumer, of the manufactured product. It is unfortunate that all five kinds of laboratories are not under research control, for the research spirit should be in all of them.

At Nela Park, the Laboratory of Pure Science is devoting intensive study to the physics, physiology and psychology of light; as an illustration, might be taken an investigation conducted on the effect of ultra-violet radiation on the eye. Fishes were exposed to such radiation under known conditions and the effects noted. It was found that opacity of the lens of the eye or cataract was produced under certain conditions one of which was the presence of calcium-chloride.

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* Abstract of an address by Dr. E. P. Hyde, director of research, National Lamp Works, at a meeting of the Division of Engineering, National Research Council, February 14, 1922.

† Address on "Selling Research," delivered by Mr. C. E. Skinner at the same meeting.

The Use of Slip-Ring Induction Motors and Synchronous Motors In Cement Mills

BY H. W. ROGERS
Associate, A. I. E. E.
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CEMENT mill machinery lends itself very readily to motor application, and while there are several direct-current motor installations, the majority of mills is driven by alternating-current induction motors.

Cement is a very fine abrasive dust and the atmosphere in a cement mill is usually heavily laden with it. As it settles on everything the natural tendency is to discriminate against the use of direct-current motors owing to the possibility of commutator trouble, but the operation of direct-current motors in mills that are so equipped does not entirely justify this attitude. There are, however, many advantages in favor of the alternating-current motor and since there are but one or two instances where variable speed is desired on any of the machines the induction motor is preferable, not only from a standpoint of power transmission and cost, but because there are, in most cases, no open contacts to invite trouble due to the accumulation of dust.

With the exception of the kiln and the tube mill, the starting conditions are not severe and squirrel-cage induction motors are always recommended, although in foreign countries there is a strong tendency to use slip-ring motors even in small sizes owing to the lower starting current and small line disturbances. Even in the case of the kiln, the starting conditions are not severe but the desire for speed variation makes it necessary to use slip-ring motors. The tube mill, however, requires from 120 to 130 per cent normal torque in starting, and although squirrel-cage induction motors have been used very extensively for this service up to 200 horse power capacity it has always been the practise to use a high-voltage compensator tap or throw them direct on the line with full voltage. This practise is not injurious to the motor but may be objectionable where the capacity of the power station is limited or where chain drive is used, as the jolt at starting introduces severe strains. It also has a tendency to crystallize the driving shaft on the tube mill, resulting in breakage and ultimate replacement.

There is, therefore, a reasonable object in using slip-ring motors on tube mills and it has become more necessary during the last few years with the development of the compeb mill which requires motors of as large as 500 horse power capacity.

In the past it has been the practise always to use enclosed collector rings wherever slip-ring motors were used due to a mistaken idea that it was essential to successful operation. The fine cement dust, although very abrasive, does not materially affect the rings or the brush contact and the only possible source of trouble is due to a collection of dust between the brushes and the holder causing the brush to stick. This trouble is remote, and with the proper design of brush holder and proper brush tension it may be entirely eliminated.

Most cement mills are equipped with compressed air which should be used at least once a week for cleaning the dust from the air ducts of the motors, and there is a strong preference on the part of a number of cement mill operators to use this means of keeping the collector rings clean rather than resort to enclosed collectors which are invisible and inaccessible.

There are certain features in the design of enclosed collectors, especially in connection with the larger low-speed motors, which are not only expensive but undesirable, and it seems unnecessary to resort to this practise longer.

Until recent years synchronous motors have not been used in the industry, but there is a growing tendency toward their application to the tube mill which is a steady load of large enough proportions to improve materially the power factor of the whole system.

Until the compeb mill was developed, 200 horse power was about the largest capacity used, and generally the motors were squirrel-cage either started from a high tap or thrown directly on the line, but with the advent of the compeb mill, especially in the larger sizes, motors as large as 500 horse power became common.

The tube mill, owing to its construction, is inherently a heavy-starting duty machine and tests have shown that from 120 to 130 per cent normal starting torque is required to meet the conditions.

The use of synchronous motors, therefore, requires that they be brought up to synchronism before applying the load, as such heavy starting torques are not available on a motor of good design unless it is also used for furnishing a heavy reactive current and is much larger than is actually required for the mechanical load.

It becomes necessary therefore, to use a clutch of some approved design to permit of starting without load. Both mechanically operated and magnet friction clutches have been used with entire success. In general, motors of this type are direct-connected to the back shaft on the tube mill through the clutch, and operate at from 160 to 180 rev. per min. A motor of the three-bearing construction or equivalent design may be used with the clutch mounted between the motor bearing and the out-board bearing, but a fourth bearing is sometimes required depending on the type of clutch used, and this is usually one of the bearings on the back shaft of the tube mill.

Where magnetic clutches are used it is desirable to have all three bearings mounted on a common iron base to preserve the alinement, but such construction is not necessarily required. The iron base may be omitted and the out-board bearing mounted on a concrete foundation.

Magnetic Clutches in the Cement Industry

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IN the early days of the cement industry, when grinding units were of relatively small capacity, motors of 75 h. p. were sufficiently large for power purposes. With the introduction of ball and compeb mills carrying heavy charges of metallic grinding medium, and the building of larger units, motors of much larger capacity were required. The modern tube mill uses a motor within the range of 200 to 600 h. p.

Being essentially a constant-speed load, there would seem to be no question but that the synchronous motor, operating at unity power factor, would be the obvious selection. The tube mill, however, requires 140 per cent to 150 per cent of full motor torque to start, even under the most favorable conditions, and the synchronous motor is not capable of exerting this high torque during the starting period. Slip-ring motors were, therefore, quite generally adopted for this service.

During this stage of development of cement grinding machinery, marked improvements were being made in the construction of magnetic clutches which were installed in large numbers in rubber mills and similar industries. Rubber mills at first made use of magnetic clutches as safety stop devices, but in 1913, synchronous motors were introduced for rubber mill drives and the magnetic clutches were used to bring the mill lines up to speed after the motor had been started light. This practise of using synchronous motors and magnetic clutches in rubber mills grew rapidly and there were soon hundreds in service throughout the country.

In 1918, a certain manufacturing company began using synchronous drive for compeb mills and installed the first unit in one of the plants of a large cement company. The combination of synchronous motor and magnetic clutch proved to be as satisfactory in the cement industry as in other industries. Other installations quickly followed and, at the present time, there are over fifty units in operation in the United States, India and Australia.

Torque Requirements

It is the usual practise to select a clutch capable of transmitting the maximum horse power which the motor can develop. That is, if a cement mill motor rated at 400 h. p. normal will develop 800 h. p. maximum, the clutch should be capable of transmitting 800 h. p. or over, depending upon the ratings of the standard magnetic clutches on the market. The clutch may be considerably larger than actually required without danger to the machine, and for this reason, some manufacturers find it desirable to use a single size of clutch to take care of a range of mill sizes in order to gain the benefits of standardization.

Operation of Magnetic Clutch

The principle of operation of a magnetic clutch is clearly shown in Figs. 1A and 1B. The field member is an electro-magnet containing an annular coil, and the armature member serves as the armature or keeper which is drawn towards the field member when the coil

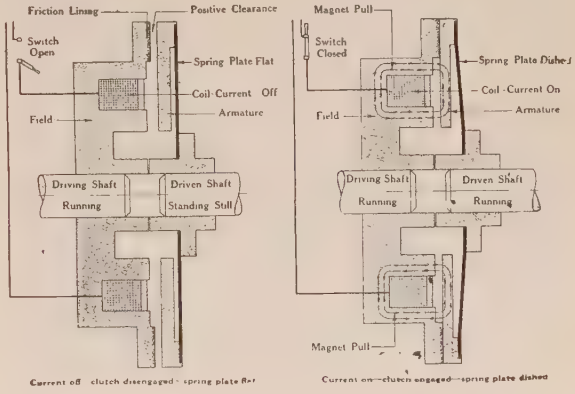


Fig. 1

is energized. On the outer rim of the field member is a flange carrying a friction surface, and the armature member is extended to come into engagement with this friction surface. When no current is flowing in the coil, the armature member stands a short distance away from the friction surface giving a positive running clearance. When it is desired to engage the clutch, the coil is connected to the line through a suitable switch and the magnetism produced in the field member draws the armature member against the friction lining. The friction between the lining and the armature member drives the load.

Starting the Tube Mill

It has been found in practise that a tube mill can safely be started by connecting the clutch directly to the line, and allowing the mill to come up to speed as quickly as the clutch permits. The results obtained by this method show that the starting period may be as short as five seconds, which in the opinion of some motor builders is too short a time to be considered

good practise. Time, however, in this case is not a measure of the safety to the machinery, since it is only a question of the forces imposed on the various sections of the units. The clutch torque-transmitting capacity being limited to approximately twice the motor torque, it is plain that the forces transmitted cannot exceed the allowable forces figured by the machine designers as safe.

Mill operators in the past have expressed a preference for a manually operated rheostat to control the excitation of the clutch during the starting period, and most of the clutches in this service are equipped with such starters. The type of starter used for this service is very simple, being of the same construction as the starter used for a five-h. p. direct-current motor, except that a special resistor layout is used. Such a starter allows the clutch torque to be regulated within limits, and the starting period can be extended several seconds longer than the starting period when no rheostat is used.

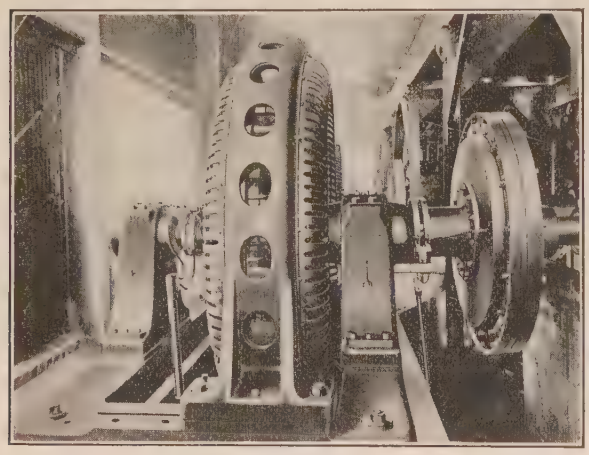


Fig. 2—Sixty-Inch Magnetic Clutches with Synchronous Motors Driving Compeb Mills in a Cement Plant

Other operators energize the clutch by closing an enclosed line switch and use no form of rheostat. Starting conditions with this operation are equally as satisfactory as when a rheostat is used. An understanding of the magnetic clutch characteristics makes clear why satisfactory starting can be expected without the use of a rheostat. A large electromagnet, such as used in the magnetic clutch, is highly inductive, and introduces a time element in the growth of the magnetic flux. Laboratory experiments have shown that it requires approximately six seconds for the average-size clutch, used in cement mill service, to reach its maximum torque after the switch is closed and full voltage is impressed at the clutch terminals.

During the first few seconds that the clutch is energized, the torque capacity is not sufficient to start the mill, and the clutch will continue to slip. During this period, however, the clutch is impressing upon the mill shaft gradually increasing torque which takes up all slack in the gears, etc. Therefore, when the clutch torque is great enough to start the mill in rotation the pull is steady and no shock is experienced, just as would be expected from a clutch having these characteristics.

There is one objection to the use of a starting rheostat. The starter may be held in a position which does not allow sufficient current to flow through the clutch coil to start the mill. For example, consider that the compeb mill requires 150 per cent full motor torque before it will start to turn. The starting rheostat may be held in a position where the clutch will not develop more than 125 per cent full motor torque. Under these conditions, the clutch would slip continuously and would never start the mill. The result would be unnecessary wear of the lining, and heating of the clutch. The standard practise of the manufacturers of magnetic clutches is to furnish clutches without rheostats, unless rheostats are specified.

Direct Current Required

Magnetic clutches require direct current for excitation, and 110 or 220 volts is suitable. The exciter generator for the synchronous motor often serves as a source of direct current for the magnetic clutch, though frequently direct current is supplied from an outside source.

Shaft Alinement

The two shafts on which the clutch members are mounted must be kept in exact alinement, if the equipment is to run without vibration. Several methods are employed to keep the shafts in alinement. The simplest and in many ways most satisfactory method is to use a three-bearing motor base plate having the clutch mounted between two of the bearings. With this arrangement, it is a relatively easy matter to maintain the shaft in correct alinement, after the installation has been made on a solid foundation. Most of the synchronous motors now in service are of the two-bearing type. There is no possible objection to this arrangement, except that it is necessary to check the shaft alinement more frequently than when a three-bearing base plate is used. Flexible couplings, both in combination with the magnetic clutch and separate from it are used with the standard two-bearing motors, and the three-bearing motors. Flexible couplings give a measure of relief from shaft misalinement and are preferred by some operators while others consider them an additional complication.

The problems entering into the design and application of clutches to cement mill services are more of a mechanical than an electrical nature, that is, the greatest problem is to build a clutch which will give years of continuous and reliable service under the conditions encountered in practise. Magnetic clutches have an advantage over clutches of any other type because the force required for the operation is developed

within the clutch structure itself instead of being transmitted from an outside source by means of sliding collars, toggles, etc. It is therefore, the simplicity of the mechanical design which is one of the most pronounced features of the magnetic clutch. It is of course highly desirable to use a clutch which may be operated simply by closing a switch, as contrasted with a mechanical clutch which may require one or several men to engage it. Reliable operation is, however, the greatest demand.

The Economics of Direct Current Railway Distribution

With Particular Reference to the Automatic Substation

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Review of the Subject.—*The comparatively recent development of the full automatic substation and also the automatic substation combined with remote control, has served to re-open the entire subject of the economics of distribution. But quite aside from the questions that the automatic substation has presented, the great fluctuations in the prices of materials and of labor have made necessary renewed study of this subject. In other words, the proper design of a distribution system should represent a balance between all of the different items of cost that go to make up the total cost of power. Any change in the relative cost of materials as against labor or of a certain class of materials as against another class of materials tends to upset such a balance. Now that we begin to emerge from the unsettled conditions of the past few years during which the old relationships have been substantially changed, it is necessary to ask the question whether or not the rules by which distribution systems have been planned in the past still apply.*

More specifically, it is the purpose of this paper to determine, first, the relations that govern the size of feeders and the correct feeder layouts for any given arrangement of substations, and second, the principles underlying the correct location, size, and type of substations, assuming the fullest development of automatic and semi-automatic control.

There is involved also the important question of stray currents. Regardless of the merits of the electrolysis controversy, the minimizing of stray currents is certainly to be desired by the electric railways. The most effective method of accomplishing this is increasing the number of distributing points. If a large number of distributing points be justified from an economic standpoint, and if furthermore this be found practicable from an operating standpoint, then the problem of electrolysis may perhaps cease to exist. Thus the inquiry is doubly pertinent.

The cost of distribution in large cities of the size of Cleveland, Detroit, or St. Louis, comprising the carrying charges on the feeder, the heating losses in the feeders and the carrying charges on the equipment necessary to supply these losses, is considerably in excess of $200,000 per year. It is apparent that a careful study of this item of cost will more than likely be justified by the savings that will result.

There are not at the present time sufficient accurate data on cost and performance of automatic substations to make possible a precise analysis of specific cases. In lieu of this it is the authors' purpose to show limiting conditions and by example to illustrate the relation of the various determining factors to the final cost.

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2. Rail and Ground Circuits.
3. Entire Distribution Circuits.
4. Distribution Distances Variable with Variable Load.
5. Generating Plant, Transmission Line and Substation Investment.
6. Operating Expenses (Generating Plant, Transmission Lines and Substations)
7. Economically Correct Substation Layouts.
8. Conclusions.
   (a) Common practise in regard to feeder sizes.
   (b) Relative Importance of substation efficiency.
   (c) Methods of operation and their effect upon substation efficiency and total cost of power.
   (d) Limitations to increasing number of substations.
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1. Feeder Circuits

THE total cost of feeder distribution comprises the following:

(1) Carrying charges on feeder investment.

(2) Carrying charges on (a) generating plant, (b) transmission lines, and (c) substations, for that part of the investment that supplies the losses in the feeders.

(3) Operating expenses of the generating plant, transmission lines and substations for that energy which is lost through heating of the feeders.

In cities of about the size of Cleveland the following conditions are fairly representative:

(1)	Feeder investment, $1,000,000. Carrying charges @ 13 per cent per annum	$130,000
(2)	Generating plant, transmission lines and substation investment per kw. (d-c.) demand, $165. At 14 per cent per annum these carrying charges are $23 per kw. Maximum demand, 40,000 kw. Distribution loss during peak, 10 per cent. Carrying charges, 0.10 × 40,000 × $23	92,000
(3)	Operating expenses of generating plant, transmission lines and substations. 0.8 cent per kw-hr. 140,000,000 kw-hr. at 40 per cent load factor 2.5 per cent average distribution loss—3,500,000 kw-hr.	28,000
	Total	$250,000

To be presented at the Annual Convention of the A. I. E. E., Niagara, Falls, Ont., June 26-30, 1922.

It is readily apparent that an increase in the copper investment will serve to cut down the heating losses and consequently those items of cost that depend on these losses. There must be, therefore, a proper size for every feeder representing an economic balance between the copper carrying charges on the one hand and the copper losses on the other, for which size the total cost is a minimum.

Three distinct types of feeders will be considered:

(a) Uniform cross-section, entire load concentrated at the end.

(b) Uniform cross-section, load uniformly distributed along feeder down to zero at end or neutral point.

(c) Uniformly tapering cross-section, load uniformly distributed along feeder down to zero at end or neutral point. This type of feeder is of course purely theoretical. It may, however, be considered as representing the limiting condition that is approached by stepping down the feeder size.

The items of cost set forth above will be expressed by the following symbols:

List of Symbols

C_F—Total annual cost of feeder circuit (dollars).
C_g— " " " " rail and ground circuit (dollars).
C — " " " " entire distribution circuit (dollars).
D —Distance to end of feeder or neutral point (feet). In the case of variable distributing distances D is the distance corresponding to peak load.
E —Voltage drop to end of feeder or to neutral point for maximum (peak) current.
E_F—Voltage drop to end of feeder or to neutral point for maximum (peak) current, in feeder only.
e —Operating expenses for generating plant, transmission lines and substation (dollars per d-c. kilowatt-hour).
f —Carrying charges on feeder in place (dollars per lb.).
G —Effective resistance of rail and ground circuit (ohms per ft.).
I —Maximum (peak) current in feeder at substation end (amperes), *e. g.* average of 15-minute peak or other basis for determining proper installed capacity.
L —Loss factor, average of the squares of the momentary feeder currents divided by the maximum current (I) squared.
m —Cross-section of feeder at substation end (circular mils).
p —Carrying charges (interest, depreciation and taxes) on generating plant, transmission lines, and substations (dollars per d-c. kw. demand per year).

The following equations in sections 1-3 (inclusive) are derived for the condition that distributing distances remain the same for all loads. The effect of varying distributing distances with load will be considered in section 4.

Type (a) feeder, uniform cross-section, concentrated load.

$$C_F = 3.67 \times 10^{-6}\, m\, D\, f + 0.001 \times I^2\, p\, D \left(\frac{10.35}{m}\right) + 8.76 \times I^2\, L\, e\, D \left(\frac{10.35}{m}\right) \qquad (1)$$

The factor 3.67 is pounds per foot per 1,000,000-cir. mil cable with triple braid weatherproof insulation, the factor is slightly greater, for smaller sizes of cable.

The first problem is to express m in terms of the constants D, e, f, I, L and p for the minimum cost (C_F), according to Kelvin's law of economy, *i. e.*,

$$m = I \sqrt{\frac{2820\, p + 24.7 \times 10^6\, L\, e}{f}}$$

$$C_F \text{ (minimum)} = 0.000390\, I\, D \sqrt{f\,(p + 8760\, L\, e)}$$

$$E_F = I \left(\frac{10.35}{m}\right)$$

Example:

Let D = 1.5 miles or 7920 feet
e = \$0.008 per kw-hr.

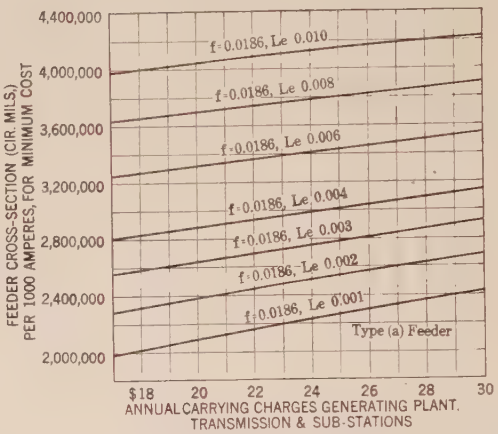


Fig. 1

f = 0.022 Multiply section by 0.9195
f = 0.025 Multiply section by 0.8626
f = 0.028 Multiply section by 0.8154
For type (*b*) feeder multiply section by 0.577
For type (c) feeder multiply section by 1.000
For 1,000,000-cir. mil, T. B. W. P. feeder multiply section by 1.000
For 500,000-cir. mil, T. B. W. P. feeder multiply section by 0.985
For 4/0 T. B. W. P. feeder multiply section by 0.985
For 2/0 T. B. W. P. feeder multiply section by 0.962
For bare feeder, all sizes, multiply section by 1.090

f = \$0.0186 = 12 per cent on feeder at \$0.155 per lb.
I = 750 amperes
L = 0.25 (For Cleveland Rwy. Co., load factor approximately 40 per cent)
p = \$23.00.

Then m = 1,860,000 circular mils.
C_F (min.) = \$2010 per annum.
E_F = 33 volts.

Type (b) feeder, uniform section and distributed load.

In this type of feeder, the above equations become (see Appendix I):

$$m = 0.577\, I \sqrt{\frac{2820\, p + 24.7 \times 10^6\, L\, e}{f}}$$

$$C_F \text{ (min.)} = 0.000225\, I\, D \sqrt{f\,(p + 8760\, L\, e)}$$

$$E_F = I/2 \left(\frac{10.35\, D}{m}\right)$$

$$\left.\begin{matrix} m \\ C_F \text{ (min.)} \\ E_F \end{matrix}\right\} \text{ for type (b)}$$

$$= \left.\begin{matrix} 0.577 \times m \\ 0.577 \times C_F \text{ (min.)} \\ 0.866 \times E_F \end{matrix}\right\} \text{ for type (a)}$$

EXAMPLE: Using the same values for D, e, f, I, L and p as in the example for type (a)

m = 1,075,000 circular mils.
C_F (min.) = \$1160 per annum.
E_F = 28.6 volts.

Type (c) feeder, tapering section and distributed load. The feeder may be considered as the summation of small increments each of which is the same as type (a)

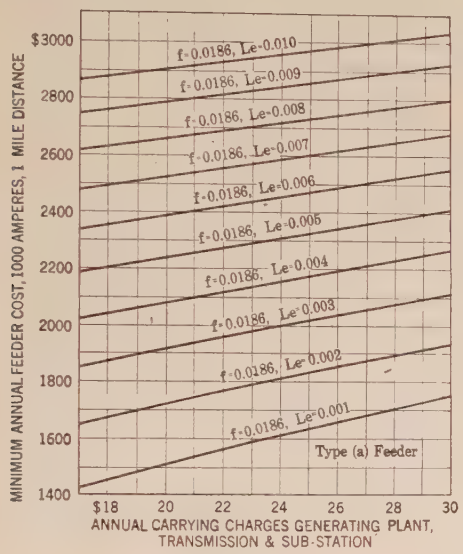


FIG. 2

f = 0.022 Multiply cost by 1.0875
f = 0.025 Multiply cost by 1.1593
f = 0.028 Multiply cost by 1.2264
For type (*b*) feeder multiply cost by 0.577
For type (*c*) feeder multiply cost by 0.500
For 1,000,000-cir. mil, T. B. W. P. feeder multiply cost by 1.000
For 500,000-cir. mil, T. B. W. P. feeder multiply cost by 1.015
For 4/0 T. B. W. P. feeder multiply cost by 1.015
For 2/0 T. B. W. P. feeder multiply cost by 1.039
For bare feeder, all sizes, multiply cost by 0.917

feeder, so that losses and amount of copper are one-half what they are for type (a). (see Appendix II.)

$$m = I\sqrt{\frac{2820\,p + 24.7 \times 10^6\,L\,e}{f}}$$

(same as for type (a))

$$C_F \text{ (min.)} = 0.000195\,I\,D\,\sqrt{f\,(p + 8760\,L\,e}$$

$$E_F = I\,\frac{(10.35\,D)}{m} \quad \text{(same as for type (a))}$$

EXAMPLE: Using same values for D, e, f, I, L and p as in examples for types (a) and (b)

m = 1,860,000 circular mils.
C_F (min.) = \$1005 per annum.
E_F = 33 volts.

2. RAIL AND GROUND CIRCUITS.

These circuits are not susceptible of precise determination principally on account of variation in joint resistance and leakage to ground. Were it not for these two factors it would be possible to calculate return circuit resistances and drops with a fair degree of accuracy. Fortunately, good practise is making this problem easier. The Report of the American Committee on Electrolysis in the "Summary of Good Practise" calls for (1) track construction and bonding that will cut down resistance to a minimum, with such cross-bonding as will serve to minimize the effect of joint failures, and (2) track insulation insofar as this is not inconsistent with other considerations. There are large differences in the resistances to ground of the several different types of roadbed construction now in vogue. Good practise, however, tends toward the roadbeds of higher resistance and the consequent reduction of stray currents.

The above report condemns the "reinforcement of rail conductivity" either by parallel copper, because this copper cannot be economically loaded, or by buried conductors which "increase the contact area between return circuit and the earth." It points out the high cost of insulated negative feeders. All of these recommendations make for the simplification of the problem which is being considered here.

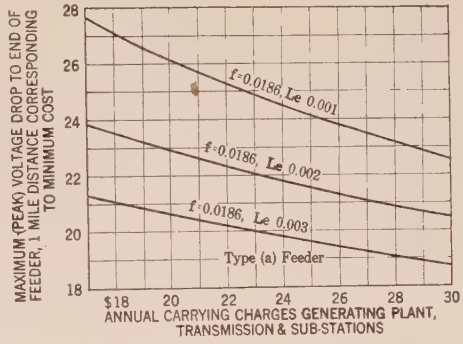


FIG. 3

f = 0.022 Multiply drop by 1.0875
f = 0.025 Multiply drop by 1.1593
f = 0.028 Multiply drop by 1.2264
For type (*b*) feeder multiply drop by 0.866
For type (*a*) feeder multiply drop by 1.000
For 1,000,000-cir. mil, T. B. W. P. feeder multiply drop by 1.000
For 500,000-cir. mil, T. B. W. P. feeder multiply drop by 1.015
For 4/0 T. B. W. P. feeder multiply drop by 1.015
For 2/0 T. B. W. P. feeder multiply drop by 1.039
For bare feeder, all sizes, multiply drop by 0.917

As the number of distributing points is increased, track drops decrease very rapidly, theoretically as the square of the distance. It is therefore apparent that decreased distributing distances will serve both to cut down stray currents and make possible the more exact determination of return circuit resistances.

For the purpose of an economic analysis the effective resistance of the rail and ground circuit in most cases may be based upon the rail resistance, without any great error. On a properly maintained city system,

current returned through other paths than the rails should not exceed 25 per cent. This is at least a rough measure of the maximum error that might result from using rail resistance as the basis for return circuit resistance. If, however, leakage is known to be approximately 25 per cent in the case of a certain line and proper correction is made for this in estimating return circuit resistance, the error should be quite small so as to be practically a negligible part of the total distribution circuit resistance.

If bonded joints are regularly tested and bad joints repaired when found, it is possible to reduce the number of joints having an equivalent resistance of less than 9 ft. of rail to 5 per cent or less of all joints. If the percentage of such bad joints be known, it becomes possible to determine the rail circuit resistance quite accurately, especially if there be proper cross-bonding. Welded joints frequently have a resistance less than that of continuous rail so that the resistance of such track may generally be assumed to be the same as for continuous rail.

The distribution of current in the track circuit will of course be the same as in the feeder provided it returns only the current of that one feeder. It follows therefore that the the second and third terms of equation (**1**) apply to the track circuit excepting that the resistance per ft. $\left(\frac{10.35}{m}\right.$ in the case of the feeder$\left.\right)$ will be changed to (G).

In those instances where the tracks return the current distributed by two or more separate feeders then the analysis of each of these separate distribution circuits may be made by increasing the track circuit resistance in inverse proportion to the ratio of the one feeder load to the sum of the feeder loads.

3. Entire Distribution Circuits

Type (a) Feeder.

$$C = 3.67 \times 10^{-6}\, m\, D\, f + 0.001 \times I^2\, p\, D \left(\frac{10.35}{m} + G\right) + 8.76 \times I^2\, L\, e\, D \left(\frac{10.35}{m} + G\right) \qquad (2)$$

$$C \text{ (min.)} = 0.000390\, I\, D \sqrt{f\,(p + 8760\, L\, e} + I^2\, D\, G\, (0.001\, p + 8.76\, L\, e)$$

$$E = I\, D \left(\frac{10.35}{m} + G\right)$$

The introduction of G into the equation does not change the value of m as previously expressed for the feeder circuit.

Type (b) Feeder.

$$C \text{ (min.)} = 0.000225\, I\, D \sqrt{f\,(p + 8760\, L\, e} + \frac{I^2\, D\, G}{3}\, (0.001\, p + 8.76\, L\, e)$$

$$E = \frac{I\, D}{2} \left(\frac{10.35}{m} + G\right)$$

Type (c) Feeder.

$$C \text{ (min.)} = 0.000195\, I\, D \sqrt{f\,(p + 8760\, L\, e)} + \frac{I^2\, D\, G}{3}\, (0.001\, p + 8.76\, L\, e)$$

$$E = I\, D \quad \frac{(10.35)}{m} + \frac{I\, D\, G}{2}$$

4. Distribution Distances Variable with Variable Load

All of the foregoing relations and equations have been based upon the assumption that the distributing distances are the same at all loads. Even with multiple-unit stations this will rarely be the case, since during light loads some stations must be shut down, in order to load the other stations up to a point of reasonable efficiency. In the case of single-unit substations in cities, it becomes necessary to follow the load by varying the number of substations in operation, and this results in larger distributing distances during periods of lighter loads. The effect of this method of operation on the above equations will be worked out by an illustration.

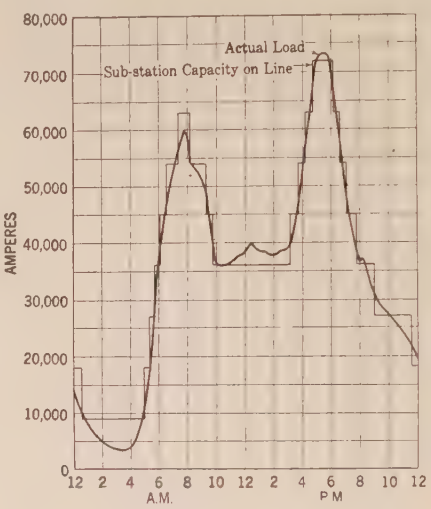


Fig. 4

The accompanying load curve (Fig. 4) shows the following of the load by putting on and taking off substation capacity. It should be possible with remote control and careful study of load conditions for the chief operator to follow the load quite closely and thus to keep all machines loaded to somewhere near rated capacity with the consequent high efficiency. It will be noted on the load curve that the substation capacity has been added in eight steps of 9000 amperes each. It will be assumed that each step represents an integral number of single-unit substations of uniform size and that the load on the different section of the systems varies about the same as the composite load curve. On a system of this kind with a large number of sub-

stations, it is necessary to use uniform section feeders between substations because of the shutting down of some substations during off-peak hours and the consequent necessity of feeding these substation areas from adjacent stations. Also on such a system the type (*a*) feeder would be used rarely if at all and the type (*c*) feeder would be used only in the outlying sections for the deadended feeders. It is therefore proper to assume that in the case of such a system as is being considered here, practically all feeders will be type (*b*) feeders (*i. e.* uniform section and uniformly distributed load).

Let D (constant) represent the distributing distance any one of substation when all substations are operating and I the proportional part of the substation rated capacity that is distributed through a single feeder. In this case, let I equal 1000 amperes. Equation (1) gives annual feeder cost for constant distributing distance (D). This equation may be expressed as

$$C_F = a\,m + b/m + c/m$$

In these equations the terms a and b will be the same as for constant distributing distance. The term b/m represents the carrying charges on that part of the generating plant, transmission line and substation investment necessary to carry the peak dis-

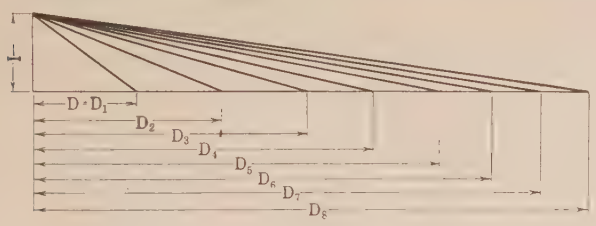


FIG. 5

tribution losses. During the peak load the distributing distance will be D (as defined above), so that b remains unchanged. The value of c, however, will be different for variable distributing distances since c/m represents the operating expenses for the heating losses twenty-four hours per day during which time distributing distance has changed several times as substations are put on and taken off the line. The value of c/m may be determined by dividing the twenty-four hours into periods within which the number of substations in operation is unchanged. On the accompanying load chart it will be seen that there are eight steps to the capacity curve and consequently for this case there are eight periods of constant capacity. Each of these periods may be treated separately and the value of c/m set down.

For the type (*b*) feeder c/m becomes $\frac{c}{3\,m}$ because of distributed load.

In Fig. 5, D_1, D_2, D_3, etc., represent distributing distances corresponding to the eight periods or steps into which the capacity curve of the system has been divided. I, which is a definite proportional part of the rated capacity of the substation, is of course constant. L approaches unity in proportion as the operator is able to make the capacity curve approach more nearly the actual load curve. During twenty-four hours the value of $\frac{c}{3\,m}$ for the distance D will be the summation of the values of $\frac{c}{3\,m}$ for each of the eight periods as follows:

$$(1)\quad \frac{c}{3\,m} = t_1 \times 2.92 \times I^2\,L_1\,e\,D_1\,\frac{(10.35)}{m} \times D/D_1$$

$$(2)\quad \frac{c}{3\,m} = t_2 \times 2.92 \times I^2\,L_2\,e\,D_2\,\frac{(10.35)}{m} \times D/D_2$$

etc.,

in which t_1, t_2, t_3, etc., are the percentages of time represented by each period. Hence for the distance D, twenty-four hours per day

$$\frac{c}{3\,m} = 2.92\,I^2\,e\,D\,\frac{(10.35)}{m}\,(t_1\,L_1 + t_2\,L_2 + \ldots)$$

Thus L in the original equation simply becomes the weighted average loss factor of the several operating periods, approaching unity in value. For the conditions represented by the load and capacity curves used in this illustration L is about 0.90. Looking at the problem in a different way, we may say that the feeders are fully loaded a much larger part of the time under this method of operation than for constant distributing distance. From an economic standpoint, therefore, larger feeder sizes are warranted because the load factor on this copper is larger. With this difference, the equations and curves already presented for type (*b*) feeders with constant distributing distance apply to the case of variable distributing distances.

EXAMPLE: Using the same values for D, e, f, I and p, as used in the previous examples for constant distributing distance, *viz.*: D = 7920 ft., e = \$0.008, f = \$0.0186, I = 750 amperes, p = \$23.00, and assuming 0.90 as the value of L

$$m = 1{,}570{,}000$$
$$C_F \text{ (minimum)} = \$1{,}690.$$
$$E_F = 19.6 \text{ volts.}$$

5. GENERATING PLANT, TRANSMISSION LINE AND SUBSTATION INVESTMENT

Generating plant investment is independent of the distribution and substation layout, where power is supplied from a central station. In making distribution calculations, the generating plant investment per kilowatt should of course include a proper amount for spare capacity. On this basis the investment will lie within the limits of \$90 and \$150 per kilowatt (undepreciated) and the carrying charges \$11.70 to \$22.50 per year.

The investment in transmission lines will vary greatly with the number and size of substations and with the arrangement of the lines. It is of course apparent that this investment will increase with the number of stations. Should the same factor of safety be required for each of many small substations as is now required of the larger substations, the increase in investment would be in some cases nearly in direct proportion. This, however, should not be the case since the failure of one small substation is of smaller consequence. If there be a very large number of substations, for example forty or more in a city such as Cleveland, it is possible that two substations might be fed safely from a single transmission line. It would appear likely that a group system could be used to advantage in cities with many small substations. This would make possible a large factor of safety without an unduly large investment in transmission lines.

In any event it becomes evident that the transmission layout must depend largely upon the seriousness of a substation failure during the peak load. This question may be answered by reference to the voltage drop equations that have been given, provided of course, that there be the proper amount of copper to meet the condition of maximum economy. The limiting condition will be found in the case of multiple-unit stations since the feeder sizes are necessarily smaller than for single-unit stations. The proper cross-section for a type (*b*) feeder would in no case be less than 1,200,000 cir. mils per 1000 amperes. The total voltage drop (peak) would be 37 volts (assuming a four-rail return circuit, properly bonded or welded, 3×10^{-6} ohm per ft.) for a distributing distance of 6500 feet. If now a substation fails, about the worst condition will be doubling the load on the feeder and doubling the distance in which case the drop becomes 148 volts. On the average city system today there is not the proper amount of feeder copper for maximum economy. Furthermore, distributing distances are great, generally two miles or more. It therefore follows that the shutdown of a substation of such a system during the peak load becomes a matter of serious consequence resulting in trolley voltages so low that it is perhaps impossible to handle the traffic. The development of the automatic substation will without doubt lead to distributing distances (for peak load) of 6500 feet or less in larger cities. It would therefore appear that the failure of a single substation on such a system should not reduce line voltages to a point where the operation of cars would be hampered.

It is next to impossible to generalize on the per kilowatt investment in transmission lines. From 25 per cent to 50 per cent of the cost of underground lines is for conduit. If power is purchased from a central station company the investment allocable to the railway load will be substantially less than it would be if the railway company owned its own generating station and transmission lines. In such cases the transmission line investment would not necessarily be increased unduly by the installation of many small railway substations. In any event it is probably fair to say that this cost, including the distributing stations of the central station company, should not exceed $30 per kilowatt for underground construction in large cities even though the substation be as small as 1000-kw. capacity. The carrying charges on this amount would not exceed $4 per kilowatt per annum. The limits for the carrying charges on generating plant and transmission lines (including power company distributing stations) may be put approximately at $14 and $27 per kilowatt per year. (The term "carrying charges" is sometimes used to include standby operating expenses; the term is not so used here).

In this analysis the demand charge of the power company, if the railway company purchase power, will take the place of the carrying charges discussed above. In most cases this greatly simplifies analysis of a particular local situation. Similarly the power company's kilowatt-hour charge, will be used in place of "operating expenses for generating plant and transmission lines."

The item of investment which will vary through the widest range with the number of distributing points for a given load, is the substation investment. For any one size of substation this cost will vary between wide limits depending upon the character of building, the cost of land, whether the station is single or multiple-unit and the character of control. There is as yet nothing approaching standard practise. Automatic and remote control equipment is still in the development stage although its workability has been proved. The writers are in accord with the opinions expressed by the "Power Generation" Committee of the American Electric Railway Association in its 1921 report[3] as follows:

> The success of the automatic idea having been proved, the principal problem at the present time is that of deciding on the most satisfactory size and number of units for a station, to secure the greatest economy while not sacrificing the quality of service. (Pg. 33.)
>
> Apparently the ideal scheme of installation is to use the smallest possible single-unit stations located at relatively short distances from each other in a very simple and small building. This type of construction will undoubtedly find much favor in the eyes of the rapid transit lines in the small cities where service requirements are not so exacting and where the traffic density never reaches a point where a service interruption results in a more or less large monetary loss. (Pg. 33.)
>
> Experimental work is now being conducted to find a solution on a full automatic basis, for the difficulties outlined above, for both machine and feeder control as encountered in Metropolitan service. However, where warranted a system of remote control superimposed upon that of the automatic control will solve the difficulties. By this method the machines could be operated dependent upon the balance between the conversion efficiency and operating cost per car mile, dependent upon average trolley voltage conditions. In this manner the operation of machines may be controlled from a dispatching center, simulating manual conditions but with greater system flexibility. (Pg. 50)

3. This committee report contains a good statement of the case of substation costs in which are shown the various factors determining these costs.

The cost of remote control over telephone wires will be so small as to be almost negligible. It need not, therefore, be specifically included in this analysis although its use, in cities at least, should be contemplated.

The curves of Fig. 6 show in a general way the limits of substation investment (without land). The upper (multiple-unit) curve is based largely upon Cleveland substation costs. The buildings for these stations are spacious, and the construction elaborate. The exteriors are suitable for residential districts. There are toilet and heating facilities and decorative lighting fixtures. The lower (single-unit) curve on the other hand represents minimum cost based upon the smallest and simplest buildings possible.

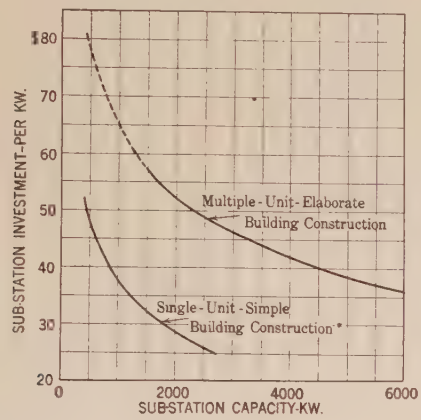


FIG. 6—AUTOMATIC SUBSTATION COSTS (WITHOUT LAND), 60-CYCLE SYNCHRONOUS CONVERTERS

*From 1921 report of A. E. R. A. Power Generation Committee

Consideration of investment charges involves the question of reserve capacity. The per kilowatt investment used in an analysis of this kind must be large enough to provide for this reserve capacity. The amount of such reserve of course depends upon the system of rating of electrical equipment. The Westinghouse Company rates its synchronous converters to permit 50 per cent overload for two hours. This amounts to 50 per cent reserve if the installed rated capacity is not less than the peak load requirements. The argument has been advanced that with small single-unit substations it is not possible to have the same reserve capacity for any one substation area excepting by the installation of a prohibitive amount of copper. This is not the case where distributing distances are not more than about 6500 ft. and feeders are of the proper size. This has already been pointed out. If under these conditions one station fails, its area will be fed through the tie lines (type (*b*) feeders) from two or more adjacent substations, the reserve capacity of which will be more than sufficient to carry the additional load. It may be seen from the previous equations and calculations that the total distribution cost is only 15 per cent more for this type of feeder than for the theoretical tapering feeder and in many cases this latter type of feeder (type (*c*)) could not be used regardless of the size or type of substation. Provided the saving in any particular case resulting from increasing the number of substations from a few multiple-unit stations to a larger number of single-unit stations is large, then the argument of the superior reserve characteristics of multiple-unit stations, is no longer valid. Indeed the reverse may hold true, because there is less chance of the failure of two equipments which are several thousand feet apart than of two machines in the same station and there may be some simplification of control equipment.

6. OPERATING EXPENSES OF GENERATING PLANT, TRANSMISSION LINES AND SUBSTATIONS

It should be pointed out here that the value of *e* in the foregoing computations includes all items entering into the cost of direct-current power excepting interest, depreciation and taxes, and that due allowance must be made for transformer, transmission and conversion losses so that *e* represents operating expenses per direct-current kilowatt-hour at the railway substation bus.

Generating plant operating expenses are independent of the distribution layout. Transmission line operating expenses will in general vary with the mileage in somewhat the same proportion as transmission investment. Unless there be a large difference in the transmission mileage required for two different distribution layouts it is probable that this item of expense may be neglected in making a comparison. It should not exceed 4 per cent of operating expenses even for very small substation installations.

The total converter substation operating expense (including maintenance) for the Cleveland manual substations is less than $0.0009 per d-c. kw-hr. Of this amount, approximately 30 per cent is for maintenance and 10 per cent for supplies; the remaining 60 per cent is for operator's wages. These figures are fairly typical, excepting that the labor cost is somewhat low because of large capacity stations. In the case of automatic control this last item is eliminated excepting for the labor of inspection and cleaning. This, together with maintenance, will increase somewhat with an increase in the number of substations used to serve a given load. For one thing, employes will have to spend more time in going from one substation to another. The transportation cost for men and supplies will also increase. The average manual substation capacity in Cleveland is approximately 6000 kw. for which the operating costs, exclusive of operators' wages are approximately $0.00036 per kw-hr. If the total operating expenses be assumed to be $0.008 per d-c. kw-hr., which is a low figure, then substation operating expense will be only 4.5 per cent. Approximately half of this amount is for labor and the rest for supplies and materials, the cost of which should not change appreciably for a larger number of small substations. Should the Cleveland system be supplied

with power from forty 1000-kw. substations, it is conceivable that the labor cost for maintenance and inspection might increase the total substation operating cost to 7.0 per cent. This would mean more than doubling present maintenance labor costs. Due to the fact that the automatic substation has not as yet

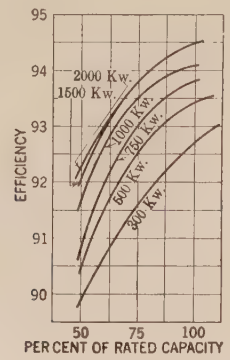


FIG. 7—COMBINED EFFICIENCIES

Three phase, 60-cycle synchronous converters, with three single-phase transformers (Westinghouse).

Ratings based on 50 per cent overload for two hours, starting hot.

come into general use, it is impossible to present precise data on operating costs. The above figure is only a guess as to an upper limit.

Another factor requiring consideration in a study of this kind is substation efficiency. Presumably at the time of peak load all substations will be operating at approximately full rated load and consequently at about maximum efficiency, no matter what scheme of layout may be determined upon. The combined efficiency of Westinghouse railway 60-cycle converters with their transformers increases about 2.5 per cent from one-half to full load. This range is somewhat less for the larger sizes (over 1000 kw.) and somewhat greater for the smaller sizes. Should the distribution system be so laid out as to necessitate operation of converters at an average of 75 per cent of rated load instead of full load, there would be a loss of 1 per cent of operating expenses per kilowatt-hour. If these operating expenses be \$0.008, then for cities the size of Cleveland, or Detroit or St. Louis, this loss would amount to about \$11,000 per year. It will be seen that this is small in comparison with total distribution costs. It is possible in some instances that smaller distributing distances and consequent decreases in distribution cost might justify the operation of certain substations at considerably less than rated capacity during off-peak hours instead of shutting down the substations and thereby increasing the distributing distances.

There is a considerable difference in the efficiency of converters with their transformers between the small and large sizes. The Westinghouse 300-kw. converter with transformers is 1.4 per cent less efficient than the 1000-kw. equipment at full load and 1.8 per cent less at one-half load. There is less difference between the larger sizes. In determining upon a distribution layout and consequently upon the size of converters this difference in efficiency must be considered. Suppose for example one layout calls for twenty-one 1000-kw. single-unit stations with an average distributing distance of 6000 feet and that the distributing cost figured out to be \$56,000 per year; and another layout calls for seventy 300-kw. stations with an average distributing distance of 2500 feet so that the distributing cost was found to be \$22,000. With a load factor of 40 per cent and power operating expenses of \$0.008 for both cases, this difference in size of equipment alone would add more than \$8,000 to the cost of power, which would be an offset to the saving in distribution cost. It must, of course, be borne in mind that other factors such as increased carrying charges and operating expenses may serve to increase the cost of power used by the cars to such an extent as to counterbalance the above apparent saving in distribution cost.

7. ECONOMICALLY CORRECT SUBSTATION LAYOUTS

We are now confronted with the application of the several principles and relationships set forth above, to specific cases with a view to determining the most economical layouts. Specifically, the problem is two-fold, (1) character of substations, *i. e.*, multiple-unit or single-unit; (2) spacing and consequently the size of substations. Several typical examples will be considered. These examples are perhaps less complex than the average actual case. They will, however, make possible the formulation of some general conclusions which, it is hoped, will prove of value in the solution of the practical problems of distribution.

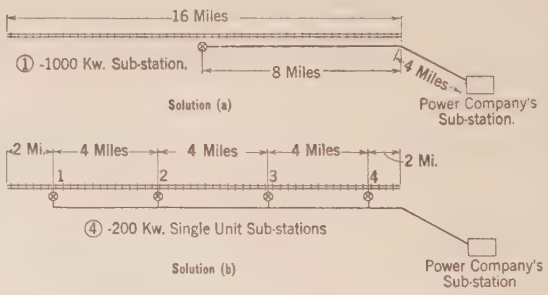


FIG. 8—SINGLE INTERURBAN LINE

Schedule speed, 20 miles per hour.

Peak headway 12 minutes.

Number of cars on line, eight (peak).

(*a*) *Single Lines*

CASE 1. Single Interurban Line. (See Fig. 8).

Length—16 miles, single track, open country.

Maximum load (with one substation) 1000 kw.

640 volts.

Load uniformly distributed over line.

Load Factor 35 per cent.

Loss factor for system 20 per cent.

High resistance roadbed—crushed stone ballast, exposed rail, bonded joints, 90-lb. rail.

No negative feeders.

Power purchased, delivery high-tension (22,000 volts) at power company's distributing substation.
Power rates— demand charge: flat rate 1.25 per kw. per month.
Kilowatt-hour charge: flat rate—$0.0075.
Substations, full automatic.
Cost of feeder in place—$0.155 per lb.

Solution (*a*) One 1000-kw. substation at middle of line, two 500-kw. units.

Cost of substation ($50.00 per kw.)	$50,000
Cost of transmission line	
4 miles—$2100 per mile (includes poles)	8,400
8 miles—$1200 per mile (using trolley poles)	9,600
	$68,000
	or $68.00 per kw.
Carrying charges at 14 per cent—$9.52 per kw. per year	$9.52
Transmission and substation efficiency at peak load = 83 per cent. Hence demand charge per d-c. kw-hr. is $1.50 per month or $18.00 per year (1.50 = 1.25 ÷ 0.83	18.00
Total carrying charges on generating plant, transmission line and substation	$27.52
Operating expenses up to purchased power delivery point (kw-hr. charge)—a-c.	$0.0075
Operating expenses (kw-hr. charge)—d-c. (Efficiency of transmission and substation—81 per cent)	0.00927
Transmission line and substation operating expenses per kw-hr.—d.c.	0.0012
	$0.01047

$L e = 0.002094$
Type (*b*) feeder cross-section (from curves) 780 amperes = 1,187,000 cir. mils. (one 1,000,000-cir. mil cable and 3/0 trolley)
Peak feeder drop[4] (8 miles = 144 volts
Rail and ground resistance (*G*) (2 rails) = 5.5×10^{-6} ohm per foot.
Peak distribution circuit drop[4] = 235 volts
Minimum line voltage[4] = 640 − 235 = 405 volts.

It should be pointed out that the condition of uniform distribution is satisfied over a period of time (*i. e.* car headway or longer period) but never nstantaneously. Hence the above minimum voltage will not be the lowest instantaneous voltage. Were there a very large number of cars on the line, these two voltages would be practically the same. With eight cars, two miles apart and one of them at the end of the line the minimum instantaneous voltage would be 345 volts. It is possible to operate the average interurban car at this voltage.

4. Average during peak period, *i. e.*, corresponds to 780 amperes uniformly distributed.

The minimum annual cost of distribution for the entire sixteen miles of this interurban line is $18,000 (determined from the equations), based upon the type (*b*) feeder. Had this been a type (*c*) feeder (*i. e.*, tapering section) the theoretical minimum cost would have been $1,840 less. Hence the cost would be between $16,160 and $18,000 depending upon the number of steps by which the section of the feeder be decreased between the substation and the end of the line. The actual cost would be about $17,000.

Solution (*b*)—Four 200-kw. substations, one 200-kw. unit per station.

Cost of substations ($70.00 per kw.)	$56,000
Cost of transmission line	
4 miles—$2100 per mile	8,400
14 miles—$1100 per mile	15,400
	$79,800
	$100.00 per kw.
Carrying charges at 14 per cent	$14.00
Transmission and substation efficiency at peak load—82 per cent, demand charges	18.28
Total carrying charges	$32.28

During the peak load period all substations will operate continuously at about full load since there will always be two cars in the distributing zone of each substation. During the off-peak periods the load may be carried in one of two ways. One or two of the substations may be operated continuously distributing over correspondingly wider zones, or all four substations may be operated intermittently as cars pass through their zones, by means of the low-voltage relays. Under the first plan distributing cost will be higher and under the second plan substation operating efficiency will be lower. Both plans will be considered here.

Assume that as the system load decreases, substations are taken off the line in the following order: No. 2, No. 4, No. 1, and No. 3. It should then be possible to keep each substation loaded on the average to at least 70 per cent of rated capacity. Whatever this average loading may be it must necessarily be substantially better than in the case of a single substation having two 500-kw. units. At full load the difference in efficiency on account of size of units will be about 1 to 2 per cent. The difference in efficiency due to the machines being loaded on the average to different percentages of rating will be of this same order, but if anything a little less. It is probable, however, that the net difference in substation efficiency between the larger two-unit station and the four smaller single-unit stations (operated under the plan of taking stations off the line as the load decreases) will be less than 1 per cent. Transmission line efficiency will not be different for solution (*b*) as against solution (*a*) since the *average* distance is the same. The combined

transmission and substation efficiency will therefore be taken at 80 per cent.

The item of transmission line and substation operating expense will be increased as against the cost for the single two-unit station. There will be six miles more transmission line and the cost of inspection and maintenance of substations will be greater for reasons already pointed out. This item will, therefore, be taken at \$0.0014 per d-c. kw-hr. Thus total operating expenses become \$0.01080 per d-c. kw-hr. as against \$0.01047 for solution (*a*).

Loss factor will be taken at 0.60. $L\,e$ is, therefore, 0.0065. Type (*b*) feeders (*i. e.*, uniform cross-section) will necessarily be used between substations in this solution because of the method of operating the substations. For the sake of simplicity, uniform section feeders will also be used on the two dead-ended sections at either end of the line.

Peak distribution losses for solution (*a*) will be

$$0.001\,\frac{I^2}{3}\,D\left(\frac{10.35}{m}+G\right)=H_a=2\times 0.001\times\frac{780^2}{3}\times 8\times 5280\left(\frac{10.35}{1{,}187{,}000}+5.5\times 10^{-6}\right)=247\text{ kw.}=24.7\text{ per cent}$$

The power used by the cars in solution (*a*) is therefore

$$1000-247=753\text{ kw.}$$

The peak distribution losses in solution (*b*) will be

$$H_b=8\times\left[0.001\times\frac{I^2}{3}\times 2\times 5280\left(\frac{10.35}{m}+5.5\times 10^{-6}\right)\right]$$

in which $m=0.577\,I\times\sqrt{\dfrac{2820\,p+24.7\times 10^6\,L\,e}{f}}=2122\,I$

Hence $H_b=28.2\,I^2\left(\dfrac{10.35}{2122\,I}+5.5\times 10^{-6}\right)=\left(I\times\dfrac{640\times 8}{1000}\right)-753$

I = 151.8 amperes. m = 322,000 cir. mils (including trolley)

H_b = 24.4 kw.

Total power = 24.4 kw. + 753 kw. = 777.4 kw.

H_b = 3.14 per cent.

The minimum annual distribution cost for the 16 miles becomes:

$$C\,(\text{min.})=8\left[0.000225\times 151.8\times(2\times 5280)\times\sqrt{0.0186\,(32.28+56.94)}+\frac{151.8^2\times(2\times 5280)\times 5.5\times 10^{-6}}{3}\times(0.001\times 32.28+8.76\times 0.0065)\right]=\$4008$$

Following is a comparison of the total power costs for solutions (*a*) and (*b*):

Comparison of Total Power Costs

Solution (a)	
Power actually used by cars:	
Investment charges—753 × \$27.52	\$20,722.00
Operating expenses—2,300,000 × 0.01047	24,081.00
	\$44,803.00
Distribution cost	17,000.00
	\$61,803.00
Solution (b)	
Power actually used by cars:	
Investment charges—753 × \$32.28	\$24,307.00
Operating expenses—2,300,000 × 0.0108	24,840.00
	\$49,147.00
Distribution cost	4,008.00
	\$53,155.00
Saving in favor of solution (b)	\$8,648.00

If, instead of cutting some of the substations off the line entirely, during off-peak periods, all substations be operated by the low-voltage relays so as to start up when a car comes within their distributing zones, then the above figures for solution (*b*) must be changed somewhat. In the first place, the average substation efficiency will be lower by reason of the stopping and starting losses. The difference is probably of the order of 5 per cent. To offset this there is some saving in cost, since the distribution distances during the off-peak periods will be the same as during the peak periods. Expressing this in the mathematical terms that have been used above, loss factor (L) becomes 0.20 instead of 0.60 as used for the other method of operation.

$$m=0.577\,I\sqrt{\frac{2820\,p+24.7\times 10^6\,L\,e}{f}}=1607.6\,I$$

$$H_b=28.2\,I^2\left(\frac{10.35}{1610\,I}+5.5\times 10^{-6}\right)=\frac{(I\times 640\times 8)}{1000}-753$$

I = 153.1 amperes.

H_b = 31.23 kw.

Total power = 31.23 + 753 = 784.23 kw.

H_b = 3.98 per cent

$C_{(min.)}$ = \$3054 or \$955 less than for the other method of operation. Operating expenses per d-c. kw-hr. become \$0.0114 or an increase of \$0.0006

$$2{,}300{,}000\times\$0.0006=\$1380.$$

It is apparent that in the case under consideration there is very little difference in cost between the two methods of operating. Under such conditions it would perhaps be better to adopt the first method (*viz.* cutting some stations off the line entirely during light load

periods rather than having these stations operate intermittently as cars come within their zones), for the reason that the additional copper provides that much larger factor of safety and also because the intermittent operation is somewhat harder on equipment.

It is apparent that a still further decrease in the size of substations, while perhaps netting some slight saving, would probably be unwise since the machines would be too small to carry the heavy swings when there are two cars in a distributing zone.

Total Power Cost as a Function of Distributing Distance—Single Lines.

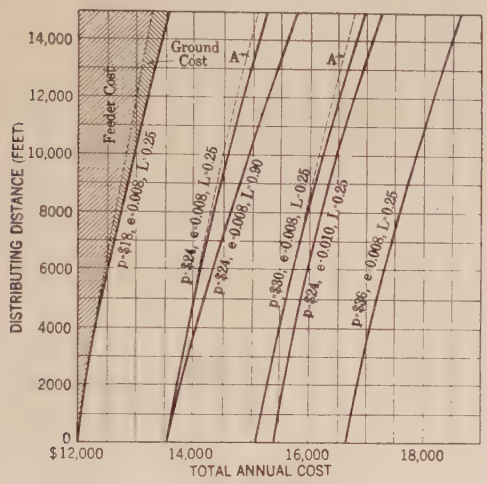


FIG. 9—ANNUAL COSTS

One-mile double track.
Uniform traffic.
Power consumption by cars, 260 kw. peak.
Return circuit resistance $= 2.5 \times 10^{-6}$ ohms per foot
Feeder investment, $0.155 per lb.
D-c. bus voltage = 600
Type (b) feeder.
Curves *A*—two-mile double track power consumption by cars, 130 kw. peak per mile.

In Appendix III the equation for D in terms of the other variable factors is derived for type (b) feeder.

This relationship is presented in the form of curves (Fig. 9). These curves serve to show the relation between distributing distance and total annual cost of power for one mile of track on which there is a uniform distribution of traffic. It will be noted that the curves have been drawn for several different values of p (generating plant, transmission line and substation investment carrying charges), for different values of e (operating expenses) and for different traffic densities (viz., 130 kw. per mile and 260 kw. per mile). From these curves it is possible to generalize to some extent upon the question of how far we may go in reducing distributing distances and still make for saving in power cost. Take for example the curve for which $p = \$24$, $e = 0.008$, $L = 0.25$, $G = 2.5 \times 10^{-6}$, and power used by cars is 130 kw. per mile. Were it possible to reduce distributing distance on the single line under consideration from 13,000 feet to 5,000 feet by the installation of additional substations, but without increasing the per kilowatt investment or the operating expenses, the saving would be $420 per year per mile of track. As a matter of fact, the investment per kilowatt would increase with the number of stations, and the question arises how far may we go in increasing investment per kilowatt and still produce a saving in the cost of power. Provided operating expenses remain substantially the same, it is clear that p may be increased to $27 per kilowatt per year before the savings from decreased distance would be offset by increased carrying charges. The increase is $3 which capitalized at 14 per cent, amounts to $21.40. Investment in generating plant will presumably be the same for all solutions of this distribution problem. Hence we may spend up to $21.40 per kilowatt on transmission lines and substations before the saving is wiped out. Suppose now that for a particular railway system, or better yet, for a particular section of this system a 4000-kw. multiple-unit station will be sufficient to feed an area such that the distributing distance on the several single lines in this area will be 13,000 feet. Suppose also that the system be such that a 1500-kw. multiple-unit station will be sufficient to feed an area such as to make the distributing distance 5000 feet. According to the curve for multiple-unit substation costs the difference in cost would be about $15 per kilowatt. Suppose now that the increase in transmission line investment is $3 per kilowatt, making the total increase $18 of which 14 per cent amounts to $2.52. By interpolation between curves it may be seen that the cost of power for the one mile of track will be approximately $7330 as against $7420 for the larger substation. The difference is $90 per year. If operating expenses, after taking account of any difference in transmission and substation efficiency, be substantially greater per kilowatt-hour for the smaller substation, then the above saving of $90 per mile will be correspondingly less. A difference of 1.5 per cent in the substation efficiency would more than offset this $90.

The above analysis is based upon constant distributing distances twenty-four hours per day. Should single-unit stations be contemplated, some of which would be shut down during off-peak periods, the curve or equations for a loss factor (L) of say 0.60 or more would be used.

The above example serves to show that the margin of saving is small for the range of distributing distances that would obtain in large cities. It shows that the investment in transmission lines and substations must be held down to bed rock minimum if there is to be any appreciable saving in the total cost of power. Furthermore, it is evident that the efficiency of equipment and all other factors entering into the total operating expenses per direct-current kilowatt-hour must be carefully weighed before the adoption of small units.

In weighing these questions of cost there is another factor which must not be forgotten. Many railway companies have found it necessary to make comparatively large investments in insulated negative feeders

and in other provisions for reducing stray currents and the consequent electrolytic corrosion of underground structures. In the foregoing analysis no account has been taken of negative feeders or other special mitigative measures. In some instances this item of cost has been large. The City of Winnipeg has recently installed the three-wire system of distribution in order to comply with a law recently passed by the Province of Manitoba which limits the allowable track drops. In considering the merits of a large number as against a small number of substations, this factor must be given weight. If electrolysis is a serious matter in a particular locality, it may prove the deciding factor in favor of the larger number of substations.

(*b*) *City Networks*

It is not possible within the limits of a paper of this kind to analyze comprehensively the entire system of any one large metropolitan city. Even if this were possible it would be of doubtful value. In lieu of such an analysis, a simple illustration will be used in which the values used for the different determining factors are typical average values for cities such as Cleveland (or Detroit or St. Louis). Were a careful analysis made for a particular city, it would be necessary to treat each line separately and to find total costs by adding up these single line results. Hence if we would generalize, it is perhaps sufficient to treat a single line on which average conditions obtain.

If the railway system be a single line (an interurban for example) or, if a city network, be considered as composed of single lines so that each substation feeds in two directions only (*i. e.*, one dimension) then distributing distance will be inversely proportional to the number of substations in operation. If the railway system be a very dense network so that every substation feeds in four directions or in effect feeds an area rather than a single line, then distributing distance will be inversely proportional to the square root of the number of stations. In the case of a large city network the relationship between distributing distance and number of substations will be somewhere between the two extremes set forth above, and as the number of substations is increased the relationship for single lines will be more nearly approached.

In the present example distributing distance has been found from the formula:

$$D = K \times (\text{Substation Capacity})^{0.75}$$

This formula expresses approximately the conditions in Cleveland. It is half way between the relationship for a single line and that for a very dense network or area.

CASE 2. Heavily loaded metropolitan system.

Excepting purchased power rates the following values are approximately correct averages for Cleveland. In place of Cleveland power rates more typical values are used.

1. Average peak power required per mile of double track—260 kw. or 0.0492 kw. per ft.
2. Substation bus voltage—600.
3. Yearly load factor—0.40.
4. Yearly loss factor for system—0.25.
5. Demand charge at power company's distributing substations—$1.00 per kw. per month. (Unity power factor).
6. System power factor unity.
7. Kw-hr. charge at power company's distributing substations—$0.006.
8. Type (b) feeders only.
9. Effective return circuit resistance (G) = 2.5×10^{-6} ohm per ft.

The total annual power cost for one mile of track will be determined for the following cases:

	Substation Capacity	Units	Distributing Distance
(a)	6,000 kw.	4—1,500	12,000 ft.
(b)	4,500 "	3—1,500	9,800 "
(c)	3,000 "	2—1,500	7,500 "
(d)	1,500 "	1—1,500	4,700 "

Substation efficiency at peak load will be the same for all of the four different arrangements. It will be taken at 94 per cent. Transmission line efficiency should also be about the same for all solutions since the mean distance to substations in a particular district should not vary greatly for a larger number as against a small number of stations. This will be assumed to be 97 per cent. Thus generating plant carrying charges per kilowatt (direct-current) become

$$\frac{\$12.00}{0.94 \times 0.97} = \$13.16$$ (*i. e.* demand charge corrected for losses)

It will be assumed that the average distance from the power company's distributing station to the railway substations will be substantially the same for the different layouts. This distance will be taken at two miles and the following transmission line capacities will be used:

(a)	6000 kw.	substation	3—4/0 cables
(b)	4500 "	"	3—2/0 "
(c)	3000 "	"	2—4/0 "
(d)	1500 "	"	1—4/0 "

The cost of cable ducts will vary from $0.50 per duct foot for nine duct banks to $1.25 per duct foot for three duct banks. As the size of substations is decreased, and in consequence the number increased, it will not be possible to utilize to the same extent the main artery duct subways of the power company, with the result that the cost per duct foot will be greater for the smaller substations. The following costs per duct foot will therefore be used: (a) $0.65; (b) $0.77; (c) $0.89; (d) $1.00. To these costs will be added $0.15 per foot for pulling and splicing and the cost of

the cable itself which will be taken at $1.45 per foot for 4/0 cable and $1.11 per foot for 2/0 cable, both being three-conductor lead-covered 11,000-volt cables. Thus the investment in transmission lines per kilowatt of substation capacity becomes: (a) $11.91; (b) $14.29; (c) $17.53; (d) $18.30. In the case of the 1500 kw. station there is no duplicate service but in this case the distance between substations is small and the shutting down of one substation is not, therefore, of serious consequence for reasons already pointed out elsewhere.

The average efficiency of transmission lines over a period of time will be about 98.5 per cent. This will not vary appreciably for the several solutions to be compared here.

Solution (*a*)—6000-kw. station-four-1500-kw. units. It would not be economical with the present cost of automatic control to operate a station of this size automatically. The same holds true for solution (*b*). Manual control will therefore be assumed for these two cases and automatic control for solutions (c) and (d).

Investment carrying charges per d-c. kw.:

Purchased power demand charges	$13.16
Transmission lines 11.91 × 0.14	1.67
Substation (manual) 30.00 × 0.14	4.20
Total (*p*)	$19.03

Operating expenses per kw-hr.—d-c.

With four machines it should be possible to keep load on each machine near capacity with resultant high efficiency, *i. e.*, 91 per cent.

Purchased power kw-hr. charge—

$$\frac{0.006}{0.985 \times 0.91} = \ldots\ldots \quad 0.0067$$

Substation and transmission line operation	0.0011
Total (*e*)	0.0078

The substation will be operated twenty-four hours per day and distributing distance will be constant. Hence L for the distribution system may be taken as 0.25.

Annual cost (from curves) for one mile of double track $13,270

Solution (*b*)—4500-kw. station—three—1500-kw. units.

Investment carrying charges per kw.—d-c.

Purchased power demand charge	$13.16
Transmission lines 14.29 × 0.14	2.00
Substation (manual) 34.00 × 0.14	4.76
Total (= *p*)	$19.92

Operating expenses per kw-hr.—d-c.

Average substation efficiency—90.5 per cent.

Purchased power kw-hr. charge

$$= \frac{0.006}{0.985 \times 0.905} = \ldots\ldots \quad 0.00674$$

Substation and transmission line operation	0.00120
Total (= *e*)	0.00794

The substation will be operated twenty-four hours per day and distributing distance will be constant. L = 0.25.

Annual cost (from curves) for one mile of double track $13,380

Solution (*c*)—3000-kw. station, two—1500-kw. units, automatic—remote control.

With substations of this size it is not desirable to operate all substations during the light load periods because to do so would mean a sacrifice of substation efficiency that would more than offset the difference in distribution cost. It should be possible to obtain an efficiency of 90.5 per cent by cutting out altogether some substations during the light load periods, that is, to equal the efficiency of the 4500-kw. station operating twenty-four hours per day. This performance cannot, of course, be had if there are very heavy load fluctuations and the machines are allowed to start and stop many times per day. This starting and stopping may easily result in an efficiency decrease of 5 per cent which under no circumstances can be justified on a large city system for it would be better and cheaper to use larger stations and distribute longer distances. Unless the load conditions be very unusual it should be possible to start and stop machines by remote control only as the regular system load increases or decreases. This method of operation will be assumed both for this solution and for solution (d). Inasmuch as the substation may be shut down a part of the time (*e. g.*, during the early morning hours), loss factor (L) will be greater, that is, the feeders will be loaded more during the light load periods than they would be if all substations were operated continuously. The exact value of L for a case such as that under consideration may of course be found for any particular load curve and plan of operation. It will suffice here to assume a value of 0.40.

Investment carrying charges per kw.—d-c.

Purchased power demand charge	$13.16
Transmission lines 17.53 × 0.14	2.45
Substation (automatic) 43.00 × 0.14 (heating, toilet facilities, etc. eliminated)	6.02
Total (= *p*)	$21.63

Operating expenses per kw-hr.—d-c.

Average substation efficiency—90.5 per cent

Purchased power kw-hr. charge

$$\frac{0.006}{0.985 \times 0.905} = \ldots\ldots \quad 0.00674$$

Substation and transmission line operation	0.00085
Total (= *e*)	0.00759

Annual cost (from curves) for one mile of double track..... $13,300

Solution (d)

Investment carrying charges per kw.—d-c.

Purchased power demand charge.....	$13.16
Transmission lines 18.30×0.14.....	2.56
Substation (automatic) 53.00×0.14....	7.42
Total ($= p$).....	$23.14

Operating expenses per kw-hr.—d-c.

Average substation efficiency—89 per cent

Purchased power kw-hr. charge—

$$\frac{0.006}{0.985 \times 0.89} \quad \ldots\ldots\ldots\ldots \quad 0.00685$$

Substation and transmission line operation.....	0.00090
Total ($= e$).....	0.00775

In this case loss factor (L) will be considerably increased over the value used in solution (c) since many of the substations will be operated only through the peak (see Fig. 4.) L will be taken at 0.60.

Annual cost (from curves) for one mile of double track..... $13,650

The foregoing calculations are all based upon the type (b) feeder since it is the most common. It is hardly necessary to repeat for the other types since the only effect would be to increase or decrease distribution costs and therefore change slightly the slope of the curves without materially changing the relative results of the several solutions. It is believed that whatever conclusions that may be drawn from these figures will apply equally to a system employing all types of feeder.

8. Conclusions

(a) The economically proper size of feeder where, as in cities, distributing distances are at most three or four miles, is such that the maximum voltage drops are too small ever to interfere with proper operation of cars. The difference in total annual cost between a properly proportioned feeder system and one designed to give the minimum voltage for satisfactory car operation is considerable, and should warrant a fairly careful examination of feeders and their loads at sufficiently frequent intervals to permit proper changes from time to time to take care of changing conditions. In general it may be said that in cities sufficient feeder copper is not used. This does not hold true to the same extent for interurban lines where distributing distances are great because economically proper trolley voltages more closely approach the minimum voltages necessary for car operation. This was brought out in the analysis for the single interurban line.

(b) The economic justification of the automatic substation is a reduction in distribution cost. In other words, the only reasons for adopting automatic control is to permit the use of small substations (3,000 kw. or less), because for such small substations the operating costs for manual control are prohibitive. The additional investment for automatic control is warranted approximately in proportion to distributing distance. Its principal field is, therefore, the interurban railway or long rapid transit line and also long electrified steam roads. In cities, on the other hand, the economic advantages of the automatic substation are relatively small because distribution cost is a correspondingly small part of total cost. For this reason automatic substation efficiency is of particular importance on city systems. A reduction of 2 or 3 per cent in the efficiency for automatic as against manual control may more than offset any saving that results from decreased distributing distance. The efficiency of automatic substations varies through wide limits for different load conditions and for different methods of operation.

(c) In a city district in which there are wide fluctuations in load, and in which full automatic control is used so that machines are started and stopped entirely by line voltage and load conditions, the average efficiency of a substation over a period of time may be reduced by as much as 5 per cent largely because of the frequent starting and stopping of machines. In many such cases it should prove far better to start and stop machines by remote control according as the average trend of the load is up or down. This may mean that the machines will be in operation for many short periods during which the load is far below their rated capacity, but even so, the reduction in efficiency resulting from such operation at a low percentage of capacity, will be of a smaller order than the reduction that may result from starting and stopping. If such a method of operation results in an average efficiency decrease of say 2 per cent or even less, it may be found more economical to shut down the substation altogether during off-peak periods. Thus it is apparent that the method of operation to be adopted and the substation efficiency that will result from such operation, must be thoroughly analyzed; otherwise, the use of the automatic substation may serve only to increase the cost of power. It is believed that in large cities it will prove necessary to adopt some form of remote control in conjunction with automatic control.

(d) The principal limitations in the reduction of substation sizes by means of automatic and remote control are (1) investment, (2) substation losses, (3) substation maintenance. In cities these factors may be increased only within very narrow limits without increasing the total cost of power. In such cities as Cleveland, it is doubtful if the capacity of substations can be profitably reduced below 3000 kw. with the control equipments now available for full automatic control, commencing at the incoming supply line and extending throughout the entire substation operation. It has been repeatedly pointed out that to produce an efficient result, some form of remote control will probably be required in order to prevent an excessive amount

of starting and stopping and the consequent loss in efficiency. Within the range of substation sizes considered in this paper for metropolitan systems (6000 kw. to 1500 kw.) the variation in total cost of power per mile of double track is small. There are, of course, some distinct advantages to be had by installing small capacity substations of say less than 3000 kw. These are principally the mitigation of electrolysis, and under certain conditions an increased factor of safety. Measures for the mitigation of electrolysis are receiving more and more attention. In a large substation having several units, trouble in one machine at peak load may result in failure of the entire station, whereas, if this capacity be separated by several thousand feet of feeder copper, trouble on a machine of one substation is much less apt to be transmitted to another machine in the adjacent substation, since the connecting circuit serves to damp out the surge.

The fact that the 3000-kw automatic substation in the examples cited apparently effects very little if any saving in the total cost of power as compared with the 4500 kw. or 6000 kw. manually controlled substations, is due to the increase in investment, substation losses, and increased maintenance, which just offset the savings in the cost of distribution. If, therefore, any substantial saving in the total cost of power is to be had by the smaller sizes of substations, automatically controlled, it will be necessary to reduce substation losses by improving methods of control. In the opinion of the writers, this should not be done by imposing upon a full automatic control substation additional remote control appliances. The complexity of such an arrangement is extremely undesirable. It is proposed that this result may perhaps be best secured by providing the simplest form of semi-automatic control substation, comprising a transmission line directly and permanently connected to the substation transformer primary circuit, and a synchronous converter arranged to start automatically from the transformer secondary circuit when the same is energized. This simplified semi-automatic control substation is absolutely under the manual control of the operator at the supply station and if the capacity of the substation be determined with regard to the economical capacity of the high-tension supply line, it may well be a single-unit station. On the other hand, if the reduction in capacity is carried to a point beyond this, a further division of a substation into smaller sizes may be had by grouping two such smaller substations on one economical supply line. Provided this method of control can be developed in a practical way, and there appear to be no serious obstacles, then there should result a substantial saving in the cost of power for substation sizes under 3000 kw. with the consequent advantages in the mitigation of stray currents and additional factor of safety as previously pointed out.

(e) Inasmuch as even a small difference in substation maintenance cost may be the deciding factor in a comparison between two distribution layouts, the standardization of substation equipment with the resultant economies is a matter of importance. While in some cases it may, at first thought, be desirable to use large units in the congested districts of a city and much smaller units in the outlying districts, it is quite possible that such an apparent advantage may be offset by an increase in maintenance expenses. The mechanism of the automatic substation is exceedingly complex and it is necessary to keep on hand a very large variety of spare parts, the investment in which is no small factor. If it be possible to adopt a standard size of unit and a standard control layout to be used in all substations, there will be an appreciable saving in the investment for spare parts. Furthermore, it is probable that maintenance labor may be reduced by such standardization. It is difficult to find and train good maintenance men and this difficulty would be substantially increased by the use of machines of various sizes and different control layouts.

Inasmuch as the heating losses in return circuits increase as the square of the current, it is apparent that smaller distances in the congested districts of a city and the consequently smaller track currents, are justified. If a substation of standard size be adopted, it would, of course, be necessary to space substations at smaller intervals in the congested districts than in the outlying districts. Other things being equal, this would be quite proper for the reason set forth above.

Appendix I

In equation (**1**) for total annual cost for type (a) feeder the heating loss is

$$I^2\left(\frac{D\,\rho}{m}\right)$$

but for the type (b) feeder in which the load is uniformly distributed, heating loss is

$$I^2/3\left(\frac{D\,\rho}{m}\right),$$

or

$$(0.577\,I)^2\,\frac{D\,\rho}{m}$$

since

$$i = \frac{I\,x}{D}$$

where x is the distance from end or neutral point to any point on feeder and

$$\text{heating loss} = I^2\int_0^{D} x^2/D^2\;\rho\;\frac{d\,x}{m}$$

$$= I^2/3\left(\frac{D\,\rho}{m}\right)$$

Appendix II

$$i = \frac{I\,x}{D}$$

$$m_x = \frac{m\,x}{D}$$

$$\text{loss} = \int_0^D i^2\,\rho\,\frac{d\,x}{m_x} = \frac{\rho\,I^2\,D}{m\,D^2}\int_0^D x^2/x\,d\,x$$

$$= \frac{I^2}{2}\,\frac{D\,\rho}{m}$$

Appendix III

Type (b) feeder.

$$m = 0.577\,I\sqrt{\frac{2820\,p + 24.7\times10^6\,L\,e}{f}}$$

$$= 30.64\,I\sqrt{\frac{(p + 8760\,L\,e)}{f}}$$

$$H_b = 0.001\,\frac{I^2}{3}\times D\left(\frac{10.35}{m} + G\right)$$

Let P = power per foot of track actually used by the cars during the peak.

Let V = substation bus voltage.

$$P\,D + H_b = \frac{I\,V}{1000}$$

$$H_b = 0.001\,\frac{I^2}{3}\times D\left\{\frac{10.35}{30.64\,I\sqrt{\frac{(p + 8760\,L\,e)}{f}}} + G\right\}$$

$$= \frac{0.000112598\,I\,D}{\sqrt{\frac{p + 8760\,L\,e}{f}}} + \frac{0.001}{3}\,I^2\,D\,G$$

$$D\left\{1000\,\frac{P}{I\,V} + \frac{0.112598}{V\sqrt{\frac{p + 8760\,L\,e}{f}}} + \frac{I\,G}{3\,V}\right\} = 1$$

$$D = \left\{\frac{V}{\frac{1000\,P}{I} + \frac{0.112598}{\sqrt{\frac{p + 8760\,L\,e}{f}}} + \frac{I\,G}{3}}\right\}$$

EXAMPLE:

Let V = 600 volts

P = 130 kw. per mile or 0.0246 kw. per foot

Load factor = 0.40

$G = 2.5\times10^{-6}$ ohm per foot

f = \$0.0186

p = \$24.00 $\qquad p + 8760\,L\,e = 41.52$

e = 0.008 } $L\,e = 0.002$

L = 0.25 }

$$\sqrt{\frac{p + 8760\,L\,e}{f}} = 47.25$$

I	D	$P\times D$	Used by Cars Kw-hr. per yr.
600	13,670 ft.	337	1,183,000
400	9,350 "	230	808,000
200	4,780 "	118	414,000
100	2,410 "	59.4	208,500

ANNUAL COSTS

	Power Used by Cars		Distribution		
	Carrying Chg.	Oper. Ex.	Feed	Rail & Ground	Total
600	8088	9464	1625	+ 160	19,337.00
400	5520	6464	740	+ 52	12,776.00
200	2832	3312	189	+ 6.60	6,339.00
100	1426	1668	47.60	+ 0.80	3,142.40

Multiply total cost by $5280/D$ for cost per mile.

7470
7220 $\qquad D = O$
7000 $\qquad$ Cost = \$6764
6895

COLOR MATCHING UNDER ARTIFICIAL DAYLIGHT

Until a few years ago it was common practise for customers in retail stores and shops to step out onto the sidewalk, while examining or matching colored goods, so that they might make their selections under daylight rather than artificial illumination. The installation of various color-matching devices, of which there are a few excellent examples in thousands of commercial establishments throughout the country, has done much to eliminate this inconvenience. By means of these lighting devices which give illumination closely approximating that of daylight, it has been made possible to obtain easily accurate color discrimination in any location where such discrimination is desired, with the result that much of the time previously consumed in the examination and color-matching of colored goods is now saved.

The St. Lawrence Seaway

BY W. L. SAUNDERS

Chairman of the Board, Ingersoll-Rand Company, New York, N. Y.

THE so-called St. Lawrence seaway is a proposition now seriously entertained, by which ocean ships may be provided with deep water navigation from the Atlantic Ocean through the great Lakes up to the head waters at Duluth. The depth proposed is from 25 to 30 feet. The cost, according to the figures given in a report of an international board of engineers, is in round numbers $270,000,000. These figures are based upon material and labor costs 80 per cent above pre-war prices and they include a hydroelectric power plant delivering about 1,700,000 horse power, this being a portion only of the potential power, which is estimated at between five and six million horse power.

To the above figures should be added about $35,000,000 which has been estimated as the cost of deepening the Detroit and St. Clair Rivers, Lake St. Clair, the Sault Ste. Marie and some work at the western end of Lake Erie in Livingston Channel, which is now 22 feet deep.

The distance from Duluth to the sea is about 2500 miles. Only about 5 per cent of this distance is involved in this canalization proposition. The balance is open water navigation in the Great Lakes, except only in the passage of the Detroit and St. Clair Rivers, the Soo and the Welland Canals.

The Welland Canal connects Lake Erie with Lake Ontario, a distance of 25 miles. The Canadian Government is now spending some $60,000,000 to provide a depth of from 25 to 30 feet in this canal.

It is an interesting and important fact in connection with this project to note that no toll charges are made or proposed throughout the St. Lawrence seaway. The passage through the Soo canal is in American territory, now free of tolls. The passage on the Welland is through Canadian territory, also free of tolls.

It will be seen that the major part of the work so far as the expense is concerned in this project is involved in the St. Lawrence River, over a distance of 116 miles from the Galops Rapids in the western part of the River to ocean navigation near Montreal. The difference in elevation or drop over this distance is 220 feet.

It will be readily seen by engineers that because of these natural conditions the best way to get deep water in the St. Lawrence is to build dams high enough to flood the Rapids. In the engineers' report it is proposed to build two or three dams, and in doing this, deep water navigation will be established over the entire distance of 116 miles. In order to get around these dams it is necessary to construct canals with locks. These canals and locks cover a distance of only about 33 miles, and it is in this distance that the largest amount of excavation and masonry work is required.

It will be readily seen how similar this is to the building of the Panama Canal. This canal is 50 miles long. At least two-thirds of it was made by building the Gatun Dam, which flooded the territory behind it, making a large open lake known as Lake Gatun. At both the Atlantic and Pacific terminals of this Lake are canals and locks (six in number). In the St. Lawrence it is proposed to build seven locks. Locks and dams require substantial rock foundations. Nature has provided this to an unusual degree in the St. Lawrence River.

I venture the statement that there has never been proposed a project so simple in its execution, so sound in its economic possibilities, and so far reaching in its consequences, as this one. If you will lay a straight edge upon the map along the line of the St. Lawrence River you will see that it points directly to Liverpool, the market for most of the grain products of the United States. Almost in the same latitude are the Scandinavian countries, also large markets for our products. The distance from Duluth to Liverpool by way of the St. Lawrence is about 5000 miles. That distance is 500 miles greater by way of the New York Barge Canal and the Hudson River, 450 miles greater by way of railroad transportation from Buffalo to New York. If it is true that the best engineering is that which accomplishes a result in the most economical manner surely it is good engineering to save between 450 and 500 miles in distance over a journey of 5000 miles. Furthermore, the record of experience shows that for every dollar which a producer in the West pays to ship products from Duluth, or other western ports, to Liverpool, more than 40 per cent (or 40 cents) is consumed in that short territory of 450 or 500 miles between Buffalo and New York. This expense is due partly to unloading and reloading charges commonly known as breaking bulk and partly to the high cost of transportation, which must of necessity be greater on railroads and canals when compared with deep water navigation.

The relative cost of rail and ocean carriage is approximately in the ratio of 100 for rail and 10 for ocean freights. This ratio is not exact for all conditions of rail or water borne carriage. Cargo carried in small, slow vessels over a long distance, as in canals or winding streams, might cost as much as rail freight, while the freight charges of the large lake bulk carriers now traversing the Great Lakes is but 6 or 7 per cent of the cost of rail freight. These bulk carriers in the Lakes provide the cheapest form of transportation in the world.

Presented at a joint meeting of the Boston Sections of the American Institute of Electrical Engineers and the American Society of Mechanical Engineers, Boston, Mass., January 24, 1922.

It is interesting in this connection to note that where noe dollar is spent to haul a ton of freight by road wagon from New York to Newark, N. J., that dollar will haul the same freight as far as Plainfield, N. J. (24 miles) over good roads by motor truck. It will haul the same freight as far as Baltimore by steam railroads. It will haul this freight from New York to Washington, D. C. and back through canals and inland waterways, and it will haul it across the Atlantic Ocean by ships.

Every time a producer in the West ships two carloads of grain to Liverpool more than one carload is absorbed in transportation charges.

Copper and zinc are now being shipped from Montana 800 miles by rail to the Pacific, thence through the Panama Canal and over a distance of 7000 miles by sea to Perth Amboy, N. J., at a cost which has been estimated at $5 a ton less than by an all rail haul east, covering a distance of only 2500 miles.

It has been estimated that wheat from the Argentine is now transported 7000 miles by sea to our Atlantic ports at an expense of 10 cents a bushel less than the cost of shipping grain from Kansas or the Dakotas by rail to the same port, this latter being only about one-fifth of the distance. The distance from Buffalo to Liverpool by way of the St. Lawrence is about the same as the distance from New York Harbor to Liverpool; that is, a little over 3100 miles. It is evident, therefore, that to break bulk at Buffalo and carry the freight to New York by canal over a period of two weeks' duration and a distance of 500 miles, or to carry it by railroad over a distance of 450 miles, almost doubles the time of delivery and almost doubles the freight charge which should be incurred if shipped from Buffalo to Liverpool direct. The St. Lawrence route is the hypothenuse of a triangle. The Buffalo-New York route runs over the other two sides of this triangle.

All navigable waters are under Federal control. The courts have decided that they should be used primarily for navigation purposes; that if water powers or other advantages develop in the use of these navigable waters they are to be considered as by-products. We may therefore, dimiss the contention that has been put forth that the St. Lawrence should be improved by private capital as a water power project.

It so happens that Nature has provided in the St. Lawrence River conditions that are admirably suited for the development of hydraulic power of enormous volume. The chief difficulty in the utilization of water powers is in getting sufficient volume of water. Volume is the main thing. Pressure or head is important but, as in the case of a boiler, better practical results are obtained through volume of steam rather than high pressure. Most water powers are subject to seasonal conditions. There is a dry season when independent generating plants must be called upon to keep the works going. Not so with the St. Lawrence. Fed as it is by that large water table tributary to the Great Lakes, there is at all times and at all seasons a tremendous volume of water passing to the sea. Navigation is interefered with during a few months in the winter season, but water power goes on indefinitely. The estimated flow is 241,000 cubic feet per second.

In order to visualize what this means let us picture a river section equal in width to the Hudson at Cortlandt Street, New York, with a depth of 40 feet and a current of moderate speed. This represents the St. Lawrence. This large volume of water over a distance of only 116 miles has a fall of 220 feet.

Electric power may now be economically transmitted and used at high voltage over a distance of 500 miles. As has previously been stated, the St. Lawrence River has a potential capacity to deliver between five and six million horse power. This might be distributed all over New England and New York, furnishing power for all of the industries and most of the railroads.

Just as deep water transportation is the cheapest transportation in the world so is hydraulic-electric power the cheapest power in the world.

In a report following a long study, recently issued by the Department of the Interior and the United Stated Geological Survey, entitled "A Superpower System for the Region between Boston andWashington" by W. S. Murray and others, the following statements are made:

> It is believed from consultation with the best informed authorities on these two projects (The St. Lawrence and Niagara Falls power developments) that power could be purchased from them at not more than $20 per horse-power-year delivered at their busbars.

Then follows a comparison between steam and hydroelectric power delivered in New England and New York, concluding as follows:

> The development of the St. Lawrence River would therefore save $11,328,000 annually to these geographic divisions. The total investment required for equipment to use the St. Lawrence purchased power would be $24,826,000 less than that required if new steam-electric plants were constructed to supply this excess energy. In the Eastern New England, Western New England and Mohawk-Hudson divisions which lie farthest from the coal fields, the cost of power generated by steam-electric plants is inherently high, and therefore the St. Lawrence development will be of very great benefit to these divisions.

It has been estimated that the use of all the potential hydroelectric power of the St. Lawrence would effect a saving in coal of fifty million tons annually. No one dreams of utilizing this power to its full measure except over a period of a great many years. It takes time and money to convert power plants from existing conditions to those which offer greater economies. But once the St. Lawrence is improved as a seaway the development of its power possibilities, together with that of Niagara, should take place gradually and economically. New enterprises would be encouraged to locate in New England and New York because of available cheap power.

As to economies of ship transportation through this route, it may be said in a general way that there is

no physical difference, so far as navigation is concerned, between the St. Lawrence seaway as proposed and any other large body of water connected with the sea. Ocean ships traverse the Mediterranean, which is in some respects similar to the St. Lawrence, having no tides. Ocean ships go up the Amazon, a distance of 2000 miles. Ocean ships go through the locks and over the waters of Lake Gatun at Panama. The Bethlehem Steel Company has recently built a 20,000-ton ore-oil carrier, to be used in Chilean ore trade. Wherein does the St. Lawrence seaway differ? It is true that ice barriers form during three or four months of the year, but the winter season is not the active season in transporting raw materials about the Lakes or in shipping grain to Europe. There is much sea navigation now in the Great Lakes. The barrier to the sea is at present the old Welland Canal and the Rapids of the St. Lawrence. Lake boats are subject to much rough weather, in Lake Superior particularly, which at times is almost as turbulent as the Atlantic. These boats furnish the cheapest means of transportation in the world, but nobody expects them to go to sea. The vast bulk of trade in transportation about the Lakes (which is now the largest in the world) comprises raw materials and other products used in our domestic markets. This should continue in increasing volume, even if only 10 per cent of it found access to the sea, because of the development of greater interior industrial centers following cheap transportation and cheap power.

Most of the important ports on the Great Lakes have now a depth of water of from 20 to 21 feet. The expense which might be incurred in deepening these ports to from 25 to 30 feet is comparatively small and should be effected largely by the communities benefited. But 20 to 21 feet of water is sufficient depth for a large proportion of freight carriers now used throughout the world. According to Lloyd's Register more than 80 per cent of all freight ships in the world have a draught under and up to 25 feet.

Ships will follow any route where navigation is deep enough and safe enough and where trade may be found. Fifty per cent of the world's commerce before the War was carried in British vessels. This supremacy was attained through wise methods of construction and operation of ships and because of large cargo, the bulk of it being iron and iron products and coal which was there ready for transportation. Seventy-five millions tons of coal were annually shipped from British ports. The population tributary to the region of the Great Lakes is as large as the population of England, but the potential manufacturing, producing and shipping advantages of the Great Lakes region are enormously greater. We have the fundamental materials of trade and commerce, namely, iron, copper, lead and zinc, gold and silver, coal, petroleum and timber, grain, cattle, sheep and hogs.

There is produced annually, in the territory tributary to the Great Lakes, of our surplus wheat 75 per cent, corn 65 per cent, flax 100 per cent, iron 85 per cent, copper 39 per cent, zinc 74 per cent, lead 46 per cent, and 50 per cent of potatoes and sugar beets, 40 per cent of the value of our manufactures, 50 per cent of the cattle and 70 per cent of the measured coal reserve.

West of Lake Superior is the great central plain of North America. Of the four billion bushels of grain produced annually in Canada and the United States 80 per cent are from this area. Minnesota is the great flour milling state and the source of our largest production of iron ore. Fifty million tons of ore are shipped down the Lake annually. About two tons or less of this Minnesota ore are required to make a ton of pig iron. German and English ores require 2½ tons per ton of pig iron. The copper of Butte, Anaconda and Calumet will find its outlet to the seaboard down the Lakes. Lake Michigan is the natural economic outlet for the agricultural and industrial products of Wisconsin, Illinois, Indiana, Iowa, Missouri, Colorado, Nebraska, Oklahoma, Kansas and for the Canadian Northwest, the Dakotas, Montana and Wyoming.

About half the population of the United States is resident in the territories tributary to the Great Lakes. Chicago is one of the world's greatest grain ports with a tributary population of some twenty-five million people and the center of the great railway trunk lines from the north, south, east, west and northwest. The agricultural production of this territory is about eight billion dollars annually, the mineral production more than one billion and a production from general industry of seven billions.

At Detroit there is annually a rail movement of 25,000,000 tons. About 6,000,000 tons go to seaboard points. It has been estimated that Detroit would absorb 500,000 tons of foreign products, if the restrictions due to the expense of railway carriage from seaboard were removed. Approximately 80,000,000 tons of freight pass the Detroit River annually.

The proximity of America's great steel industries to the Lakes will permit of large economies in the transportation of their products by the St. Lawrence route to Atlantic ports of the United States and to foreign countries. Pennsylvania and New York, with territories bordering on the Lakes are placed at an advantage over New England in the shipment of raw materials for manufacturing purposes and in the distribution of manufactured goods. The St. Lawrence seaway would give New England cheap water transportation for raw materials such as food products, coal and iron, with an opportunity to distribute its manufactured goods, such as textiles, shoes, etc., to that great territory of the Middle West tributary to the Great Lakes. The distance to New England ports is about 2000 miles by water and only about a third of that distance by rail, yet the cost of transportation by sea should be at the rate of 3 mills per ton mile or $6 per ton as against 1¼ cents per ton mile by rail. Where it costs one dollar to haul by water from Chicago

to Boston it will cost three dollars by rail. Mr. H. I. Harriman has estimated that on the present basis of consumption, the St. Lawrence seaway would effect a saving to New England of $15,000,000 a year.

If copper from Montana can be, as it is, shipped West to the Pacific through the Panama Canal and up to New Jersey at a price less than railway carriage east, and if the products of Argentina may be transported to eastern ports cheaper than by rail transportation across the continent, it seems reasonable to expect that the St. Lawrence seaway will be a means by which New England industries may receive great benefits in transportation economies.

A project that is economically sound, especially when it involves transportation of goods on a large scale, is sure to benefit the people as a whole in all the territories affected. A ship channel which connects two territories, in each one of which there is a large production of goods, is a wise project and is sure to prevail in the end.

The great producing areas of America, so far as raw materials are concerned, are situated a thousand miles from tidewater. In this respect we are hadicapped in competition with Argentina, India, Russia and other territories, where the production is at or near tide-water.

Cheap transportation through the Great Lakes and not cheap mining of ore is the prime reason why America leads the world in economic steel production. England obtained her supremacy in coal production because her mines were at tidewater. In this respect American mines are at a disadvantage.

The outlet to the St. Lawrence seaway is in Canadian territory. Much of the work proposed is also in Canadian territory, but the waters of the Great Lakes are in international territory. A ship channel leading to the sea is of advantage as a means of transportation through the territory. What does it matter that the Suez Canal should run through the deserts of Africa and Asia? What does it matter that the Panama Canal should run through the swamps of Panama? The advantage is getting through. Producers at both ends are benefited more largely than those on the borders of the channel.

For more than one hundred years there has been perfect peace between Canada and the United States. We have recently listened to propositions for proportioning armaments among nations. That proportion was fixed more than one hundred years ago by Canada and the United States at 0 to 0. Furthermore the way to keep peace among individuals, among corporations and among nations is to cultivate mutual association and interests as against competition and conflict.

An International Joint Commission has for a long period of time been investigating the St. Lawrence seaway project. This Commission is composed of equal representatives from Canada and the United States. It has unanimously recommended the St. Lawrence seaway, advising that the cost of all navigation works be apportioned between the two countries on the basis of the benefits each will receive from the new waterways; that during the period ending five years after the completion of the works the ratio fixing the amount chargeable to each country shall be determined upon certain known factors, such as the developed resources and foreign and coastwise trade of each country within the territory economically tributary to the waterway. That ratio to be adjusted every five years thereafter and to be based upon the freight tonnage of each country actually using the waterway during the previous five year period. That the cost of navigation works for the combined use of navigation and power over and above the cost of works necessary for navigation, alone should be apportioned equally between the two countries.

This Commission further reports as follows:

> The evidence seems to show that existing depths in the Detroit and St. Clair Rivers, Lake St. Clair and the St. Mary's River, as well as in most of the principal harbors of the Great Lakes, would accommodate a large proportion of the vessels now operating on the high seas.

In the report of this Commission is the following statement:

> The commission believes that while it is physically practicable to bring both railroads and terminals up to the point where they could handle the traffic of the United States without serious congestion the expense involved would be enormous, amounting in the opinion of experienced railroad executives, to $2,000,000,000 per annum over a series of years, and it is perhaps questionable if in the end the relief afforded would be comparable to that promised by the creation of an all-water route from the interior of the continent to the Atlantic seaboard.
>
> Of the alternative routes suggested, the New York State Barge Canal, the projected Oswego ship canal, the Richelieu and Lake Champlain route, the proposed Georgian Bay canal, the Hudson Bay route, the Mississippi route and the Pacific and Panama Canal route the commission is convinced that none of them offer the advantages of the St. Lawrence route either as a means of relief for the acute transportation situation or as a channel for the carriage of ocean borne commodities.

Eighteen western states have by legislative enactment and executive order endorsed the St. Lawrence seaway. It has also the approval of the Mississippi Valley Association; it has the approval of former Secretary of Commerce Redfield; the present Secretary Mr. Hoover has endorsed it with the statement that it is the greatest single step in the direction of national efficiency. Its practicability from a shipping standpoint is endorsed by Mr. Magnus Swenson, President of the Norwegian American Line, by Mr. Julius H. Barnes, of the U. S. Grain Corporation, whose company ships 40 per cent of all the wheat sent to Europe. Mr. Barnes has figured that it will add a value equal to 5 cents a bushel to every grain producer in the West.

A project like this, which will make seaports along thousands of miles of American territory and which at the same time will furnish to New England and other eastern states cheap power, is surely worthy of our earnest consideration and interest. It may be carried out without burden to the people through the issuance of bonds endorsed by the United States and Canada and sold in the markets of the world.

ILLUMINATION ITEMS

By the Lighting and Illumination Committee

ILLUMINATION AND TRAFFIC ACCIDENTS*

In order to obtain, if possible, some definite measure of the value which should be attributed to the proper illumination of streets as a factor in the prevention of traffic accidents, a comprehensive survey was undertaken, the results of which are given below. To obtain as high a degree of uniformity as possible in the collection of the data, blank forms were prepared providing for a charting of all traffic accidents in a given city during the period of one year and for distributing them as to the month and hour of the day at which each occurred, with notations as to whether or not the accident resulted in a fatality. A representative group of cities was selected and individuals in each who were known to be interested in problems of public safety were requested to arrange for the tabulation of the data. The work of tabulating accidents from the city records was often tedious on account of the way in which the accident reports were filed. In some instances the accident data were not available. The very cordial response to the request for cooperation in this survey is, however, attested by the fact that tabulated reports in form to be directly applied were obtained from 32 cities with a combined population of over 7,000,000. From each of these cities the report covered a full year's accidents; in most cases during the period from the middle of 1919 to the middle of the year 1920. The names of the cities and an abbreviated summary of the tabulation for each city are given in Table I. The total number of street traffic accidents reported for one year in these 32 cities was 31,475 of which 9,534 or 30.3 per cent occurred during hours of darkness. It was anticipated that there might be considerable variations in conditions existing in individual cities located in different states and it was, therefore, particularly desired to obtain a sufficiently diverse group of cities including a large enough total of population to give the presumption of a reasonable degree of accuracy in the results.

The 31,475 traffic accidents are charted in Fig. 1, according to the total number during each month. In certain cities special local influences, such as an excess of traffic at some one season of the year changed the distribution of accidents considerably but in most cases the individual reports adhered to the trend shown by the average curve in Fig. 1. At first thought it is somewhat surprising to note that there was a greater number of accidents in the summer months than in the winter as there are a number of influences which tend to increase the hazard in winter, such as stormy foggy weather, slippery streets, and the impediment of heavy clothing. However, as a matter of fact, the traffic is so much greater during summer months than in winter that even in spite of the unfavorable conditions in winter the accidents are more numerous in the summer than in the winter months in most cities.

The total accidents reported for the year are charted in Fig. 2 according to the hour of the day during which

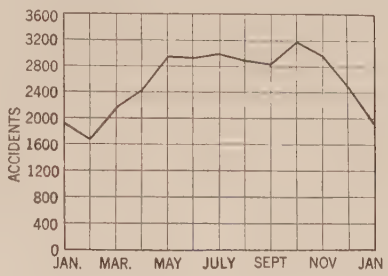


FIG. 1—TRAFFIC ACCIDENTS BY MONTHS

they occurred. This chart shows also the apparent importance of density of traffic as a factor in causing accidents. It will be noted that relatively few accidents are reported in the hours from 1 to 7 o'clock in the morning, the period of the day in which street traffic is least. On the other hand, the accident rate becomes greatest in the hour from 5 to 6 in the afternoon when in practically every city the streets are congested with the home-going population from offices, stores and factories.

An obvious and simple way of determining how many of the 9,534 accidents which occurred after dark would have been avoided had daylight or its equivalent been available, is to compare the number of accidents

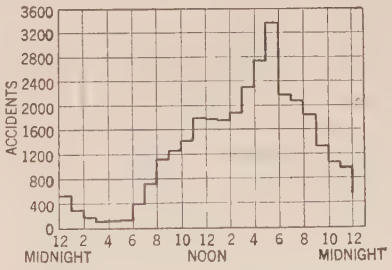


FIG. 2—TRAFFIC ACCIDENTS BY HOURS OF THE DAY

which occurred during the hours in the evening which were daylight in the summer with the number of accidents which occurred during the same hours in winter when because of the shortness of the day it was dark. Consultation of tables of sunrise and sunset applying to the different cities involved indicated that the hours 6 to 8 p. m. were the two hours of the day which are fully light in the months of May, June and July and entirely dark during the months of November, December and January.

It is evident, however, that a ratio between the accidents occurring from the hours 6 to 8 p. m. in summer as against the number that occur during the corresponding hours in winter would not show directly the influence of light because of the numerous other variables referred to above which have an influence that must be taken into account.

*Extract from paper presented by E. A. Anderson, and O. F. Haas before the Fifteenth Annual Convention of the Illuminating Engineering Society, Sept. 26-29, 1921, Rochester, N. Y.

Fortunately the accident statistics for the hours of the day which are light in both summer and winter or which are dark in both summer and winter, offer a convenient means for determining a correction factor to take into account the variables other than light which affect the number of traffic accidents in winter and summer. The periods of 3 to 5 p. m. and 9 to 11 p. m. are the logical selections because of their adjacency and the consequent similarity of traffic to that in the 6 to 8 p. m. period. In Table I there is shown in tabulation, by cities, the totals of accidents for the respective periods of 3 to 5 p. m., 6 to 8 p. m., and 9 to 11 p. m., separated so as to show the number of accidents during these hours in the summer months of May, June and July, and the winter months of November, December and January combined.

TABLE I

TRAFFIC ACCIDENT STATISTICS FOR THIRTY-TWO CITIES DURING A PERIOD OF ONE YEAR

	Traffic Accidents Reported									
					3—5 p. m.		9—11 p. m.		6—8 p. m.	
	Total	Night	Total Fatal	Night Fatal	Winter*	Summer	Winter*	Summer	Winter*	Summer
Philadelphia, Pa.	5231	1485	190	66	175	251	71	98	164	183
Cleveland, Ohio	3549	1059	174	56	120	120	89	73	154	121
Boston, Mass.	3380	1001	89	38	108	159	57	69	117	131
Pittsburgh, Pa.	2950	982	6	2	119	183	57	100	74	109
San Francisco, Cal.	3014	1092	76	32	127	106	58	73	110	84
Jersey City, N. J.	672	223	28	13	18	38	8	17	36	32
Rochester, N. Y.	2570	735	29	9	70	111	34	71	62	119
Portland, Oregon	1230	411	31	8	45	43	11	21	38	48
Columbus, Ohio	193	95	17	9	7	11	6	13	8	7
Hartford, Conn.	1389	300	19	6	38	72	12	17	37	57
Grand Rapids, Mich.	255	78	12	4	9	8	1	7	10	12
Youngstown, Ohio	702	258	33	15	33	31	12	17	28	25
New Bedford, Mass.	699	189	7	3	34	40	6	17	20	31
Lynn, Mass.	818	278	7	2	35	40	19	20	36	42
Utica, N. Y.	652	150	9	3	22	43	2	25	16	33
Fort Wayne, Ind.	1010	241	9	2	42	30	14	13	29	19
Peoria, Ill.	131	26	7	3	5	11	1	1	5	1
South Bend, Ind.	143	46	6	3	6	6	5	6	7	5
Portland, Maine	620	177	1	..	16	24	9	16	20	18
Charleston, S. C.	192	52	13	3	6	8	..	7	8	3
Rockford, Ill.	181	45	11	3	5	15	3	5	3	9
Saginaw, Mich.	120	48	3	..	..	7	2	3	8	5
Holyoke, Mass.	287	79	5	2	15	13	5	2	5	15
Gary, Ind.	281	78	10	4	5	11	3	13	6	12
Malden, Mass.	187	56	3	...	3	9	..	5	3	13
McKeesport, Pa.	74	30	2	..	1	1	1	3	2	6
New Castle, Pa.	74	31	3	1	3	2	..	5	2	12
Mt. Vernon, N. Y.	264	78	2	1	11	12	3	7	8	12
Evanston, Ill.	287	81	9	4	7	17	2	7	6	11
Austin, Tex.	169	75	2	2	9	3	2	2	16	9
Muskogee, Okla.	42	20	2	..	..	3	1	1	2	9
East Cleveland, Ohio	109	35	6	4	1	1	1	6	6	7
Total	31,475	9,534	821	298	1,095	1,429	495	740	1,046	1,200

*Winter refers to November, December and January.
Summer refers to May, June and July.

Referring to the totals in Table I, and taking first the hours from 3 to 5 p. m. which are daylight in both summer and winter, the number of accidents is found to total 1,429 in summer and 1,095 in winter. The winter accidents from 3 to 5 p. m. are, therefore, 76.6 per cent of the summer total. Considering next the totals for the period of 9 to 11 p. m. which is dark both in summer and winter, it is noted that the accidents are respectively 740 and 495. The winter accidents from 9 to 11 p. m. are, therefore, 66.9 per cent of the summer total. If these two percentages of 77.6 and 66.9 are averaged it is indicated that for the groups of cities in this survey, traffic conditions are such that excluding the influences of illumination the winter accident rate in the afternoon and evening is approximately 71.8 per cent of the summer accident rate.

Considering next the period of 6 to 8 p. m. which in summer is daylight, Table I shows a total of 1,200 accidents in the 32 cities during the three months of May, June and July. Hence, applying the average percentage of winter to summer accidents (71.8 per cent) determined as above it would be anticipated that in the three winter months of December, January and February, there would be 862 (71.8 per cent of 1,200) accidents during the hours of 6 to 8 o'clock p. m. However, the survey shows a total of 1046 accidents to have actually occurred during these hours in the three winter months or 184 more than anticipated provided there had been the same effectiveness of illumination in the winter months as in summer. Hence, there is the strongest evidence that 184 accidents or 17.6 per cent of all those at night must be attributed to the lack of light during the winter months. Applying this same percentage to the 9,534 accidents which occurred after dark in the 32 cities covered by this survey it appears that 1,678 would have been avoided if adequate illumination had been provided.

The percentage of 17.6 arrived at as the proportion of night accidents which may be attributed to lack of light is undoubtedly an extremely conservative figure

to use in evaluating the usefulness of illumination in preventing traffic accidents, for, as a matter of fact, the streets of all of the cities covered in the foregoing survey were illuminated at night by artificial lighting of varying degrees of effectiveness. In an individual city where the need for better street lighting is specially evident the percentage of night accidents chargeable to the lack of light is likely to run as high as 50 per cent. On the other hand, in the case of those districts where fairly high levels of artificial street lighting are provided by so-called White-Way systems, the percentage of night accidents chargeable to lack of illumination can be said to be fairly low. It was hoped to have data from this survey to show the difference but it was not found practical to separate the statistics for the better lighted sections in a sufficient number of cases to arrive at an average figure.

LUMINAIRE VS. FIXTURE OR LIGHTING UNIT

For several years there has been more or less agitation among illuminating engineers against the term "fixture". This was undoubtedly because the suggested permanence of lighting equipment was regarded as a serious deterrent to improving lighting installations. This feeling has been stimulated, since, with the development of certain new wiring devices, it is proposed to "hang a fixture like a picture."

A removable fixture seems to represent a contradiction. Likewise, the term lighting unit has been considered objectionable because of its clumsiness and ambiguity. The question of an improved term received extended consideration in the Illuminating Engineering Society's Committee on Nomenclature and Standards. Out of a number of terms proposed, the Committee considered "luminaire" to be the most acceptable. The Committee's recommendation was presented and discussed at the Rochester convention of that Society, and has since been accepted by the Council.

The term has been submitted to other engineering and trade societies to ascertain their attitude towards its adoption. It is reported that the Lighting Sales Bureau of the National Electric Light Association has voted to encourage its use. Favorable comment has been received from many other quarters, and as might be expected, there has been some opposition from engineers who considered a new term neither necessary nor advisable.

"Luminaire" possesses the advantage that it is not a coined word, but that it is already in use in this connection in the French language. The Illuminating Engineering Society's Committee considered it equally appropriate and understandable in English. Success will, of course, depend largely upon usage, but from indications so far, it appears to have a very fair likelihood of taking a place in the language of the lighting art.

STYLES AND TENDENCIES IN LUMINAIRE DESIGN

Impression from the Annual Lighting Fixture Market, Milwaukee

By S. G. Hibben
Westinghouse Lamp Co.

Several hundred prominent manufacturers of interior lighting devices exhibited in February 1922, in Milwaukee, the newest things in electric fixtures and glassware. Thousands of units were on display, presumably representing the best average home, store, and office lighting equipment that has been developed during the past year.

The super-artistic luminaires were not included in this exhibition—at least not such types as would be built only for a particular setting in a peculiar interior, and consequently would be odd or distinctive styles and of little value in interpreting the trend of the art. Neither were purely commercial units much in evidence, and factory lighting devices almost not at all. But even with these exceptions, there was an ample quantity of luminaires to guide the illuminating engineer in predicting the tendencies and styles for some months in the future.

A brief survey of this market will be interesting. While discussing the recent developments, one must keep in mind the fact that business and building for the past twelve months have not particularly encouraged radical growth along any new line, nor has any new illuminant called forth special shielding or reflecting accessories. On the other hand, the manufacturers are appreciating more the fact that engineering skill can be mixed with artistic talent in developing those units which can be both true to period and harmonious in style, even though this idea seems so far to have been applied mainly to store and office luminaires. Residence units still are products of the period artist, and perhaps properly so. The result of the years growth might be best expressed in stating that the new styles of luminaires are drifting into two classes; one, unit designed primarily for illuminating purposes; second, units which are patently for decoration and must be accepted as such.

Of the first group, utilitarian luminaires, the totally enclosing globe seems to be most in evidence. Squat or flattened shapes having a large downward projected area and a smaller horizontal area, are popular. This tendency reflects the study of photometric distribution tests, because such shapes result in higher illumination beneath the unit and less glare when viewed at angles close to the horizontal. For office and store uses, the long stalactite shapes of globes are passing out of style.

Enclosing globes are simple to use, partially because they are not rapid collectors of dirt, but mainly because they are in large measure fool-proof. Wrong positions of light sources within good diffusing globes may result in non-uniform or non-efficient illumination, but at least such glaring and optically harmful faults cannot result from them as are too frequently found from a large gas-filled lamp projecting far out from beneath a small shallow reflector.

These globes have called forth new thought in the design of better holders. Two facts are evident in holder development; first that the set-screw is not the summum maximum as regards mechanical satisfaction or safety support; second, that the popular future holder will have some socket adjustment, thus enabling the use of perhaps two sizes of lamps in one size of globe.

It may be noticed that glassware manufacturers are realizing that close competition demands a very careful perfection of the globes, to reduce light absorption to some percentage certainly less than 25 per cent, and to utilize every available lumen that the lamps can produce. Even such small items as white enameling of the interior of the holder, or a flat silvered reflector over the fitter opening are receiving attention.

Ventilation of enclosing globes is to become, if it is not already, an engineering matter, not "just a hole in the bottom of the glassware." Past practises of haphazard ventilation design is passing. Most of the globes exhibited were without bottom holes; such holes are not needed if due thought is used in properly cooling the lamp socket.

Among the exhibits of the second group viz., residence lighting luminaires, one may note the remarkably extensive use of round-bulb diffusing lamps, chiefly on colonial candelabra. Unless these lamps are of the amber color, or better still, unless they are shielded by small ornamental shades, the resultant glare is annoying. The grace of such luminaires is pleasing; their illuminating value is not so good if the lamps used are bare. Hence, there have appeared a few small candelabra shades in ornamental glass and parchment and curved-glass bracket shields.

The silk shaded ornamental table lamps remain popular. Some of these are veritable works of art, especially those built upon glazed vases, or of medieval wrought metal.

Polished and brushed brass, remain in the lead by ample margins, followed closely by the silver finishes of metal residence luminaires. Colors of lighting devices that blend or harmonize with interior colors are rather slow in coming but it appears that more and more thought is being given to special finishes, to polychrome or enameled and tinted parts, and to silk cords, tassels, decorative chains, and the like.

The removable luminaire—"hanging a fixture like a picture,"—is yet in the embryonic stage commercially, although it is well perfected mechanically. Like all great reforms, it has much inertia to overcome.

CORRESPONDENCE

POLYPHASE COMMUTATOR MACHINES

To the Editor:

An article under this heading appears in the January issue of the JOURNAL, attributed to myself. In spite of the title the Article itself deals with only one type of frequency changer, and even for that machine only discusses some of the I^2R losses, but the broad titles which appears above the article has no doubt arisen by reason of the inclusion, through some inadvertence, of the matter contained in a hastily compiled memorandum dealing with another subject, and not intended for publication; this composes the first five paragraphs and the first (unnumbered) figure of the article in question.

The error would have been avoided had proofs been submitted to me, but in the circumstances perhaps you will allow me to make some necessary corections now, in the part referred to.

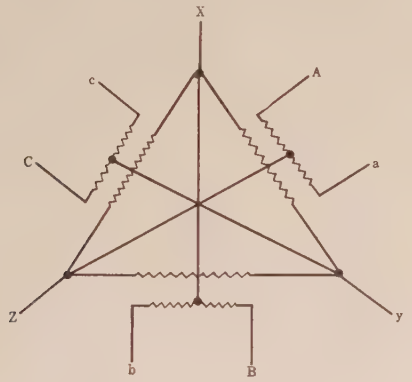
On page 50 of the JOURNAL in the fourth paragraph of the article, reference is made to the characteristics which may be expected from a machine comprising an induction motor stator and a rotor having a commutator, both stator and rotor having closed windings with the same number of conductors. The rotor is supposed to be running at twice synchronous speed in the same direction as the air-gap field, and the three phase brushes to be in line with the three phase tapping points of the stator winding, or at 180 dég. to the same, according as the coil progression of the rotor winding is the reverse of, or the same as that of the stator winding. It is suggested that as the same air-gap field would be produced by a lagging magnetizing current in the stator winding as by a leading current in the rotor winding, the requisite magnetizing current might be induced to circulate between stator and rotor connected in parallel to the bus bars without the necessity of any magnetizing current being introduced from outside; also that the small $I\,R$ voltage required to cause this circulation might be produced by a slight shift of the brushes, while the small $I\,X$ voltage component at right angles to this, corresponding to the stator and rotor leakage fluxes associated with the magnetizing current only, might be introduced by an a-c. exciter, interposed between the line and the machine.

The statement needs a little modification in as much as the shift of brushes which provides the requisite $I\,R$ voltage for the circulation of magnetizing current produces at the same time a compounding effect, and would therefore have to be determined by the amount of such compounding desired; the balance one way or the other would have to be obtained otherwise, for instance by the transformer connection referred to later. Further, the $I\,X$ voltage required would automatically appear by a slight slip arising, that is, by the air-gap field taking up a speed of rotation slightly different from half the rotor speed; therefore no a-c. exciter need be postulated. For operation with shunt characteristics the brushes would be left in the normal position, and a small quadrature voltage would be injected between the stator and rotor to overcome the $I\,R$ drops corresponding to the circulation of magnetizing current only; this quadrature voltage might be introduced by the delta-connected transformer arrangement shown in the appended figure, the lines $A\,B\,C$ going to the stator and $a\,b\,c$ to the rotor, while $X\,Y\,Z$ pass to the

busbars. The transformer might advantageously have a moderate magnetic leakage.

The last two statements of the fourth paragraph substantially stand, to the effect that in a machine such as here described the field rotates in the same direction as the rotor at approximately half the speed of the rotor so that a rotor conductor cuts the field in a direction opposite to that in which the stator conductor, immediately confronting it, cuts the same field, the two speeds of cutting being nearly the same; and that therefore, whether the machine be running as a generator or motor, almost complete compensation takes place of the stator ampere conductors by the rotor ampere conductors immediately confronting them and the machine becomes closely self-regulating.

It will be seen further that although the machine operates with some slip, it behaves more like a synchronous generator or motor than an induction machine inasmuch as there is one combination of frequency speed and voltage which forms a consistent set of conditions, and the only natural flexibility in the relation between the frequency and speed is that introduced by saturation which causes a variation in



the ratio between the IR and IX components of voltage requisite for circulating the magnetizing current. The slip will not change sign between generator and motor conditions of operation, in fact it arises only to provide voltage for circulating magnetizing current and not for load current. A slight variation in frequency with speed fixed can be artificially secured however by introducing an external inductance in the path of the circulating magnetizing current; such inductances may, if desired, be so arranged as to be substantially non-inductive to the passage of load current, although inductive to the circulation of magnetizing current. Similarly the voltage can be varied with speed fixed, or with frequency fixed, by varying the ratio of the transformer shown in the figure, or by introducing an external resistance in the path of the magnetizing current, but unlike the inductance the resistance can only be introduced in a manner such that it opposes the load current as well as the magnetizing current.

For parallel operation or for stable running as a motor, a certain amount of effective reactance will be necessary either internal to the machine or accessory. In this respect also the conditions are similar to those which arise with synchronous machines.

These features of operation are detailed here, not with the intention of claiming practical utility for the arrangement, but merely to correct the somewhat erroneous view of the matter which has already been printed in the article in question.

While upon this subject it may be of interest to consider the conditions arising at twice synchronous speed in the frequency changer dealt with in the main part of the article. If we assume the rotor of say a three-phase frequency changer of this type to be independently driven at twice synchronous speed in such direction that the frequency is the same on the commutator as on the slip rings, we have two three-phase systems of equal frequency and voltage associated with the machine. The phase rotation on the commutator is the reverse of that on the slip rings considering corresponding brushes but nevertheless the two three-phase systems can be paired and brought into phase with one another and then there would seem to be no objection to paralleling them on to common bus bars. The machine will then be running on the bus bars without distress with commutator brushes solidly connected to slip ring brushes, a somewhat paradoxical condition. Here again the arrangement is of theoretical interest only and has no practical utility, it acts neither as generator, motor nor converter; it might serve as a filter to short-circuit all effects other than those of fundamental frequency.

Glancing over the main part of the article I note that ambiguous signs are invariably printed with the plus as the upper and the minus as the lower sign, whereas they should be reversed in the case of the expressions numbered 8, 12, 13, 14, 15 and in the definition of a on page 55. Without these corrections the tabulation would appear to be wrong and the matter troublesome to follow.

A. B. Field.

MESSAGE TO THE ENGINEERS OF AMERICA*

The ease and promptness with which the public as a whole becomes accustomed to and takes advantage of the work of the engineer, using the term in a broad sense, is almost startling. Surprise at, and fear of radical innovations in transportation and private service quickly give way to blase indifference followed instantly by all manner of criticism that these things are not better constructed and managed. Does the street car stop a few minutes on a switch?—summon the State Commission. Is the Overland Express fifteen minutes late on a three thousand mile run?—Congress is memorialized to make the great railroad companies attend to their business; everyone apparently for-

*Abstract of speech by Dexter S. Kimball, dean of engineering at Cornell University, and vice-president of the American Engineering Council, broadcast from the General Electric Station, Schenectady, N. Y., April 4, 1922.

getting how steep the hills were before the days of street cars, how far away San Francisco was before the days of the locomotive, the telegraph and telephone, and how difficult it must have been to study by the light of a tallow candle.

Now these little outbursts should not be construed (as they are by some people) as indicating a lack of appreciation of the work of the engineer. They are an integral part of the influence that makes for progress. The work in a way has always obtained as much engineering talent as it demanded. Criticism is a part of progress.

If the engineer has not been appreciated as much as some other classes of men it is because his service to humanity has not been the highest. The men who render the greatest service to any nation are those who mould its ideals, and the philosopher and the poet will continue to wear the bays as long as they lead in this line. True, the work of the engineer has made it possible for us to realize more fully our ideals if we could only take full advantage of the productive processes which he has developed and the leisure that should result therefrom; for every day it becomes clearer that highest mental and moral development rest primarily on material prosperity. It is difficult to be high-minded and hungry at the same time.

Every calling becomes of greater service and rises in popular estimation as it lifts itself from the mire of empiricism and rests its work on the solid ground of science. Medicine and engineering and similar professions have increased their usefulness and prestige in proportion as the chemist, the physicist, the anatomist, and other workers in pure sciences have furnished scientific facts and as these professions have been able to apply them.

The engineer most naturally applied his scientific method to constructive engineering and it has become second nature with him to collect data, to analyze the same and to plan work and predict results on this solid basis. But the administration of modern industry has come to require a considerable knowledge of constructive art, and the natural tendency to seek a solution of the problems of administration on the basis of accumulated knowledge rather than on an empirical basis has made one opportunity for the engineer that has carried him far afield and brought him closely in touch with the administrative side of both private and national affairs.

To this new field he has, quite naturally, brought the analytical methods of his calling, and the art of management bids fair to be placed on a much more rational basis because of his labors in this new field of activity. The progress which this movement makes will, as before noted, depend not on the effectiveness of these methods alone but on the reactive influences which it meets with or awakens.

Efficiency is not the sole criterion by which industrial phenomena are to be finally judged. Whether we will it or not, industry is being looked upon more and more as a means of supporting human existence and less as a means of creating individual or cooperative dividends. The most efficient kind of factory over the creating of dividends would be equipped with the highest order of labor saving machinery and management and operated by slaves.

And as we move further and further away from this extreme ideal so we shall become more and more critical of processes and methods of production. It is going to be a nice problem in social and political organization to reconcile the many conflicting reactions, and the full import of the movement will be more and more appreciated as our natural resources become more depleted and the struggle for existence becomes keener.

The influence of this new study on the engineer himself will be far reaching; for he must draw his basic facts for this work not only from his own field of engineering but also from economics, accounting, psychology, and other sciences which heretofore he has known little or nothing about, or has ignored. And this has brought him very close to the pivotal problem of our civilization, namely, the fair and equitable distribution of the wealth which he is so instrumental in creating.

If he can master the fundamental truths that lie at the bottom of the problem or if he will have the wisdom and foresight to call to his aid the masters of thought in these lines it is not beyond reason to hope that as he has conquered the problems of production and is now conquering the problem of administration he may evolve from his riper experience in these fields a solution of the remaining problem which will be satisfactory to all. It is apparent that the solutions already offered fail to satisfy; but it by no means follows that these are the only possible solutions any more than the old methods of management were the only ones possible.

In fact as we look back even a few years the philosophies of engineering and manufacturing as then practised seem very inadequate indeed; and the theories of management of yesterday are rapidly passing into obsolescence. We are sadly in need of a new type of industrial philosophy and new methods of distribution. We are in need of a new type of industrial leader; and I believe that if he comes at all in the near future, he will come from the ranks of the engineer, again using the term in the broadest sense.

Here is his opportunity. It is hardly likely that any one man will be able to solve this difficult problem and if it is solved it will probably be the work of many brains. But the man who first points out the way to a solution will not need to envy any man his glory for posterity will surely place him in the ranks of the immortals.

I have every confidence that the engineer will rise to this opportunity and there are many things that these ideals are stirring in the minds of forward-looking engineers.

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A. I. E. E. Annual Convention

NIAGARA FALLS, ONTARIO

Plans for the Annual Convention of the Institute to be held at Niagara Falls, Ontario, June 26-30, have been matured during the past month by both the Convention Committee and the Papers and Meetings Committee and some innovations in the general plans are to be adopted this year which it is believed will add to the interest and general convenience of those attending the meeting.

The technical program has been practically completed with the exception of assigning the papers to the sessions at which they will be presented. The plan of the Meetings and Papers Committee this year is to start the program with the most highly specialized papers and to follow these on successive days with papers dealing with broader subjects, ending with the more general and least specialized papers. To meet the general demand for social events the afternoons are to be left open for games, excursions, etc., and in order to provide sufficient time for the technical sessions without curtailing other activities it is planned to hold some parallel sessions in the mornings, in which cases the papers presented at the two parallel sessions will be on widely varying subjects which will be chiefly of interest to entirely different groups of those attending the convention.

It is planned to devote Monday, June 26th, to meetings of the Sections Committee. At previous Conventions the Delegates meetings have been hampered by lack of time, as it has been the policy of the Board of Directors not to schedule any committee meetings simultaneously with the technical sessions, and this has had the effect of limiting these meetings to evening sessions which were extended into the small hours of the morning. By devoting a special day to the Sections it will not only give ample time for exchanges of experience and discussions of policies but also will leave the Delegates more opportunity to take part in other convention activities.

TENTATIVE TECHNICAL PROGRAM

The technical program is made up of five main groups of papers and in addition several papers on a variety of subjects, ranging all the way from pure physics to practical mechanical engineering. There are 25 papers scheduled, to date.

The six groups, briefly stated are: (a) The New Queenston Plant, (b) Standards of Rating of Generator Insulation, (c) The Baltimore Oil Circuit Breaker Tests, (d) Symposium on Engineering Education, (e) Papers on Miscellaneous Subjects, (f) Insulation and Rating of Electric Cables. The titles and authors of the papers in these groups follow:

(*a*) *Four papers describing the Queenston Plant and its 45,000-kv-a. generators and transformers. These machines are of the largest capacity ever put into a single unit. A visit to the Queenston Plant is scheduled for the first afternoon of the Convention.*

1. *The Queenston Plant*, by F. A. Gaby.
2. *Queenston Generators, 45,000 kv-a. Description of the Canadian General Electric Company's Generator, 187½ rev. per min. Vertical, 25-cycle, 12,000-volt, three-phase*, by B. L. Barns.
3. *45,000-kv-a. Queenston Generators*, by R. A. McCarty.
4. *Design Features of Main Power House Transformers Queenston Station*, by M. E. Skinner.

(*b*) *Three papers relating to the Standard of Rating of Class "B" Insulation, and Conventional Allowances for Generators.*

5. *Questions Relating to Standards of Rating, with Particular Reference to Large Machines Using Class "B" Insulation*, by F. D. Newbury.
6. *Probable Values of Conventional Allowance for A-C. Generator Stator Windings*, by F. D. Newbury.
7. *Temperature Limits in Large Machines*, by P. Torchio.

(*c*) *Three papers relating to the Baltimore tests of Oil Circuit Breakers. These are the highest power tests ever made. As a result of these tests the interrupting capacity of circuit breakers was extended to handle successfully the short circuit currents of the largest power systems. At a risk to its apparatus the Power Company of Baltimore supplied an unprecedented amount of power in cooperation with the manufacturers of circuit breakers.*

8. *Baltimore Oil Circuit Breaker Tests*, by H. C. Louis and A. F. Bang.
9. *Oil Circuit Breaker Tests—Interrupting Capacity Tests of General Electric Oil Circuit Breakers at Baltimore*, by J. D. Hilliard.



A. I. E. E. ANNUAL CONVENTION HEADQUARTERS



HORSESHOE FALLS ILLUMINATED

10. *Tests on Westinghouse Oil Circuit Breakers at Baltimore*, by J. B. MacNeill.

(*d*) *Six papers of the Symposium on Education. The viewpoint in these papers is that of the employer of the college graduate.*

11. *Suggestions Concerning the College Education of an Engineer*, by C. Hering.

12. *Training for Character*, by A. M. Dudley.

13. *Some Suggestions for Possible Improvement in Methods of Engineering Education*, by B. G. Lamme.

14. *What may be Done by Engineering Schools to Better Prepare Students for Railway Work, with Special Reference to the Telegraph and Telephone Department*, by I. C. Forshee.

15. *Education*, by S. E. Doane.

16. *Principles of Engineering Education*, by P. Torchio.

(*e*) *Other papers on variety of subjects already chosen for the Summer Meeting.*

17. *Higher Steam Pressures or Pulverized Coal?* by F. A. Scheffler.

18. *The Economics of Direct Current Railway Distribution (with particular reference to the Automatic Sub-Station)*, by L. P. Crecelius and V. B. Phillips.

19. *The Two-Stage Current Transformer*, by H. B. Brooks and F. C. Holtz.

20. *Two Thousand Tests on the Dielectric Strength of Liquid Insulation* by J. L. R. Hayden and W. N. Eddy.

21. *A General Law of Electromagnetic Forces*, by C. Hering.

(*f*) *A group of four papers relating to Electric Cables.*

22. *Dielectric Losses and Stresses in Relation to Cable Failures*, by D. W. Roper.

23. *On the Minimum Stress Theory of Cable Breakdowns*, by D. M. Simons.

24. *Determination of Temperature of Electrical Apparatus and Cables in Service*, by E. J. Rutan.

25. *Effect of the Composite Structure of Impregnated Paper Insulation on the Electric Properties*, by W. A. Del Mar and C. F. Hanson.

THE SOCIAL EVENTS

Every afternoon is set aside for recreation and trips to surrounding places of scenic and technical interest. Arrangements are being made for musicals, popular lecture, dancing, cards, golf, tennis, baseball and other forms of indoor and outdoor recreation.

A. I. E. E. Annual Meeting

The Annual Business Meeting of the Institute will be held in the Engineering Societies Building, New York, Friday afternoon, May 19, 1922, at four o'clock. The results of the annual election of Institute officers will be announced and the report of the Board of Directors for the year ending April 30 will be presented. President McClellan, who will preside, will make an address relating to Institute affairs and the subject will then be open for discussion.

Prior to the Annual Business Meeting, the Board of Directors will hold a regular bi-monthly meeting; and in the evening there will be a dinner to the members of the Board of Directors, the past-presidents, and the president-elect, for an intimate discussion of the Institute and its development.

The Spring Convention

The Spring Convention of the A. I. E. E. was held at the Drake Hotel, Chicago, Ill., April 19-21, 1922. The program was well balanced, including specialists' papers, general papers and entertainment, offering a diversity of interests which appealed to all those in attendance. The technical sessions were notable in the amount of prepared discussion presented. The local convention committee took charge of the registration

and maintained a general information bureau for the benefit of out-of-town members and guests, in addition to exercising a general supervision over all of the convention activities.

Wednesday Afternoon

The first technical session was called to order by President McClellan who made a very brief address predicting an era of great activity in engineering work and especially an era of cheap electric power which is essential to the development of our industries which are in competition with the cheaper labor of foreign countries. He then introduced Mr. P. Trombetta who presented his paper on *The Electric Hammer*. Discussion followed by R. E. Hellmund and H. L. Wallau. The next paper presented was by Mr. F. W. Dunmore, entitled *A Relay Recorder for Remote Control by Radio*. This was discussed by E. E. F. Creighton, W. de L. Carr, Mr. Schraber, H. L. Wallau, A. C. Forbes, P. Trombetta and F. G. Clark. The final paper of the session was on *Magnetic Flux Distribution in Transformers*, by K. B. McEachron and was abstracted by the author. It was discussed by R. E. Hellmund. H. L. Wallau, E. E. F. Creighton, B. F. Bailey, A. Still, J. E. Clem, A. H. Mittagg, P. Trombetta, W. McClellan and Morgan Brooks.

Wednesday Evening

Visiting members at the convention were guests of the Chicago Section of the A. I. E. E. at a theatre party Wednesday evening at the Aryan Grotto Theater. A musical comedy entitled "Kitty Corner" was given by the Haresfoot Club of the University of Wisconsin. The book, lyrics and music were written entirely by undergraduates, who also composed the cast, chorus and orchestra. The play was very cleverly produced and many of the musical numbers received numerous encores.

Thursday Morning

The Thursday morning technical session was called to order by President McClellan who turned the conduct of the meeting over to Mr. H. R. Woodrow, chairman of the Protective Devices Committee. The paper on *Air-Brake Magnetic Blowouts*, by J. F. Tritle was abstracted by the author and this was followed by the paper on *The Effects of High Currents on Disconnecting Switches*, by H. C. Louis and C. T. Sinclair. These two papers were jointly discussed by H. D. James, written discussion by Mr. O'Neill read by F. C. Hanker, P. Trombetta, J. H. Milliken, A. F. Bang, H. C. Louis, B. G. Jamieson, H. L. Wallau, E. E. F. Creighton, C. T. Sinclair and H. B. Dwight by letter.

The chairman next introduced Dr. Karl W. Wagner, of Berlin, who presented from manuscript a paper on *Characteristics of Insulation*. This was discussed by D. W. Roper, R. E. Hellmund and J. E. Clem. This paper, which is to be revised to include the results of some of Dr. Wagner's most recent experiments, will be published in a future issue of the Journal.

Thursday Afternoon

The session on Thursday afternoon was devoted to a very informal discussion on the subject of "Transmission of Energy from Coal Mines to Large Centers of Distribution." President McClellan in opening the session announced that no report of the meeting would be published and therefore the speakers might express their opinions unreservedly. Those taking part in the symposium were L. E. Imlay, P. Junkersfeld, R. F. Schuchardt, E. W. Anderson, H. L. Wallau, P. Trombetta, F. G. Clark, A. H. Armstrong (by letter), W. R. Abbot, L. A. Ferguson and James Lyman.

Thursday Evening

The dinner-dance was held in the ball room of the Drake hotel Thursday evening and was highly enjoyed by all in attendance. The affair was informal, and dancing continued until midnight.

Friday Morning

The session Friday morning was devoted to papers under the auspices of the Industrial and Domestic Power Committee, and President McClellan after calling the meeting to order turned it over to Mr. W. C. Yates, Chairman of that committee. The first group of papers related to crane equipment and was as follows: *Selection of Electrical Apparatus for Cranes*, by R. H. McLain, in whose absence it was presented by J. J. Matson; *Auxiliary Electrical Equipment for Motor-Operated Cranes*, by H. W. Eastwood, presented by the author, and *Electric Crane Controllers*, by J. F. Schnabel, abstracted by Mr. Eastwood. These papers were discussed as a group by C. A. Bird, P. Trombetta, A. G. Pierce, H. D. James and A. J. Acker.

The last paper of the session was entitled *Electric Power Application to Passenger and Freight Elevators*, by H. P. Reed, and was presented by the author. An extensive discussion followed by Messrs. H. D. James, J. J. Matson, C. B. Bradisch, A. Liebenberg, R. E. Hellmund, D. L. Lindquist, E. B. Thurston, T. E. Barnum and W. H. Patterson.

Friday Afternoon

Two inspection trips were provided for Friday afternoon by the Convention Committee, one to the new Calumet Station of the Commonwealth Edison Co., where turbo-generators of 30,000 kw. capacity are in operation, and the other to the automatic substation of the Chicago, North Shore and Milwaukee Railway. Each of the trips was attended by a large party and the entire afternoon was devoted to the inspection of the two stations.

Friday Evening

One of the most interesting features of the Convention was the symposium on "The St. Lawrence Seaway" Friday evening, and an added feature of interest was the fact that the addresses were broadcast by radio through the courtesy of the American Telephone and Telegraph Co., the Westinghouse Electric & Mfg. Co. and the Commonwealth Edison Co.

The meeting was called to order by President McClellan who, after a brief survey of the subject, introduced Col. Hugh L. Cooper, consulting engineer of New York, who gave an address on *The Improvement of the St. Lawrence from the Viewpoint of Private Capital*. This was followed by an address by Hon. S. Wallace Dempsey, Chairman Committee on Rivers and Harbors, House of Representatives of U. S., on *The St. Lawrence Seaway from the Viewpoint of the Government, the Port of New York, and the Barge Canal*. The last speaker was Mr. Henry I. Harriman, Vice-chairman, Massachusetts Commission on Foreign and Domestic Commerce, whose subject was *The St. Lawrence Seaway Project in its General Aspects, and the Utilization of the Electrical Energy*.

Mr. Julius H. Barnes, formerly president U. S. Food Administration Grain Corporation, and U. S. Wheat Director, was scheduled to present an address on *The Effect of Transportation Economy via the St. Lawrence Waterway on the Farm Price of Three Billion Bushels of Grain Tributary to the Western Lake Ports*, but sent a telegram to the meeting expressing regrets at his unavoidable absence.

These addresses which gave an excellent survey of St. Lawrence seaway project from various important viewpoints, will be published in future issues of the Journal.

Florida Engineering Society

ANNUAL MEETING, DAYTONA, FLA., MAY 15-17

Members of the A. I. E. E. are invited to attend the annual meeting of the Florida Engineering Society, to be held in Daytona, Fla., May 15 and 16, 1922. The meetings will be held in the Casino Burgoyne. Additional information may be obtained from the Secretary, Prof. J. R. Benton, Gainesville, Fla.

Future Section Meetings

Atlanta.—May 25, 1922, Georgia School of Technology, Y. M. C. A. Auditorium. Subject: "Industrial and Commercial Lighting." Speaker: Mr. H. R. Spaulding, National Electric Light Association, Cleveland, Ohio.

Baltimore.—May 19, 1922, Engineers Club, Light and Redwood Streets, Baltimore, 8:15 p. m. Subject: "Application of Electricity to the Steel Industry." Speaker: Mr. R. B. Gerhardt, electrical superintendent, Sparrows Point Plant, Bethlehem Steel Corporation.

May 20, 1922, 1:00 p. m. Inspection trip to the Sparrows Point Plant of the Bethlehem Steel Corporation.

Cleveland.—May 16, 1922, Hotel Statler. Annual Dinner Meeting. Speaker: Dr. William McClellan, president, American Institute of Electrical Engineers.

Detroit-Ann Arbor Section.—May 12, 1922, University of Michigan, Ann Arbor, Mich. Subject: "Engineering Research in Industries." Speaker: Professor C. F. Hirshfeld, of the Detroit Edison Company.

Erie.—May 16, 1922. Subject: "Twelve Months of Electrical Development." Speaker: Mr. H. Hansen.

Fort Wayne.—May 18, 1922. Annual Business Meeting and Election of Officers.

Lynn.—May 10, 1922, G. E. Hall, West Lynn. Annual Business Meeting.

Philadelphia.—May 8, 1922, Engineers Club, 1317 Spruce Street. Subject: "The Coming of the Alternating Current." Speaker: Mr. B. G. Lamme, of the Westinghouse Electric & Manufacturing Company.

June 14, 1922, Howard McCall Field, Philadelphia. Annual Meeting.

Utah.—May 26, 1922, Commercial Club, Salt Lake City, Utah. Subject: "Mine Signaling." Speaker: Mr. Abner R. Willson, electrical engineer, Utah Apex Mining Company. Election of officers.

Vancouver.—June 2, 1922, Auditorium, Board of Trade Building. Subject: "Electric Power for Irrigation." Speaker: Mr. C. R. Yuill. Election of officers.

Scholarship in Electrical Engineering at Columbia University

The governing bodies of Columbia University have placed at the disposal of the American Institute of Electrical Engineers a scholarship in Electrical Engineering in the Schools of Mines, Engineering and Chemistry of Columbia University, beginning with the academic year 1922-23 and continuing until further notice. The scholarship pays $350 toward the annual tuition fees which vary from $340 to $360, according to the details of the course selected. Reappointment of the student to the scholarship for the completion of his course is conditioned upon the maintenance of a good standing in his work.

To be eligible for the scholarship, the candidate recommended will have to meet the regular admission requirements, in regard to which full information will be sent without charge upon application to the Secretary of the University or to the Secretary of the Institute.

In a letter addressed to the Secretary of the Institute, an applicant for this scholarship should set forth his qualifications (age, place of birth, education, reference to any other activities, such as athletics or working way through college, references and photograph). A committee composed of Messrs. Francis Blossom, F. B. Jewett and W. I. Slichter will consider the applications and will notify the authorities of Columbia University of their selection of a candidate. The last day for the filing of applications for the year 1922-23 will be July 1, 1922.

The course at the Columbia School of Mines, Engineering and Chemistry, is 3 years in length and is on a graduate basis. A candidate for admission must have had something of a general education, including considerable work in mathematics, physics and chemistry. Three years of preparatory work in a good college or scientific school should be sufficient, if special attention has been given to the three preparatory subjects mentioned. A college graduate, with a Bachelor of Science degree in engineering, can generally qualify to advantage. The candidate is admitted on the basis of his previous collegiate record, and without undergoing special examinations. Other qualifications being equal, members of Student Branches of the Society will be given preference.

The purpose of this advanced course is to produce a high type of engineer, trained in the humanities as well as in the fundamentals of his profession. It is hoped that members will show a keen interest in this scholarship, which will insure the choice of a candidate of the highest qualifications.

American Engineering Standards Committee

CONFERENCE ON COLORS FOR TRAFFIC SIGNALS

New York City, May 23, 1922

The American Engineering Standards Committee, in accordance with requests received from the Illuminating Engineering Society and from the International Traffic Officers' Association to determine the desirability of standardizing the colors used for traffic signals, has called a conference on this subject to be held Tuesday, May 23, at 10:30 a. m., in the Engineering Societies Building, New York City.

There is being placed on the market and in use, semaphore control apparatus having numerous colored lights at variance with each other and at variance with colored lights used for other purposes along the highways, thus leading to confusion and to numerous accidents. In the opinion of the above organizations there is need of a thorough study of colors for traffic signals in order that there may be national uniformity in the use of colored lights for such purposes. If the conference decides that the unification of colors for traffic signals shall be undertaken, it will determine upon the scope of the work, and recommend the procedure to be followed.

It is expected that included in the scope of the work will be the use of colored signal lights on automobiles, bicycles, tractors, trailers and horse-drawn vehicles; their use on semaphores and other position signals along highways and at curbs; methods of specifying or defining colors for such uses; and the relation of such lights to railway signals, to temporary danger signals placed along highways, and to fire exit signals.

The status of the subject and the facts bearing on it as they exist in the automobile, steam railway, electric railway and regulatory commission fields will be outlined in a few brief papers in order to lay a proper foundation for the discussion of the necessity for and feasibility of developing standard colors for traffic signals.

PORTLAND CEMENT SPECIFICATIONS NOW AMERICAN STANDARD

The "Specifications and Tests for Portland Cement," for which the American Society for Testing Materials is sponsor, have been advanced to the full status of "American Standard" by the American Engineering Standards Committee. These specifications, which have been developed as a result of the experience of the industry through several years, were first approved by the A. E. S. C. as "Tentative American Standard" in 1919. They were reapproved in 1921 after agreements had been reached which eliminated slight differences between the Government and the commercial specifications, resulting in nationally recognized uniform specifications.

National Exposition of Power and Mechanical Engineering

A national exposition of power and mechanical engineering will be held in New York City from December 7 to 13, 1922. Plans for the exposition include exhibits of every type of machine, equipment, instrument and the various materials and supplies necessary in the operation of the complete power plant. The advisory committee for the exposition under the chairmanship of I. E. Moultrop, of Boston, is comprised of Milan R. Bump, N. A. Carle, A. G. Christie, Fred Felderman, E. B. Katte, Dexter S. Kimball, Fred R. Low, David Moffat Myers, Calvin W. Rice; and the managers are Charles F. Roth and Fred W. Payne, with offices in Grand Central Palace, New York.

Second Annual Convention of Institution of Engineers, India

The second annual convention of the Institution of Engineers, India, was held in Bombay during the week beginning Monday, January 30,1922, at which time new officers for the year were elected. The new President is Major G. H. Willis, C. I. E., M. V. O., R. E. The Institution of Engineers is made up of engineers of all branches as it was considered that there was not a sufficient number of representatives of any one branch of the profession in India to warrant individual associations. Local sections of the Institution have been formed in Calcutta, Bombay and Madras and the membership has reached a total of over 500 with prospects of doubling that number before long.

American Engineering Council

MEETING IN PITTSBURGH, MAY 26-27

The next meeting of the executive board of American Engineering Council will be held in Pittsburgh on May 26 and 27.

INDUSTRIAL SURVEY UNDERTAKEN

A survey of American industry to ascertain "what steps have been taken to smooth out the business cycle" has been started by the American Engineering Council of the Federated American Engineering Societies. Each member organization will be enlisted in the task of covering the industries in its locality. A special committee of the Washington, D. C., Society of Engineers has been appointed to cooperate with the federation.

Secretary Hoover previously presented to the executive board of the American Engineering Council, through the executive secretary, L. W. Wallace, the question of a proposed investigation of intermittent unemployment and cyclical depressions as an outcome of the work of President Harding's conference on unemployment.

"The largest area of waste lies in the periods of slack production and unemployment due to the ebb and flow of economic tides between booms and slumps," said Mr. Hoover, quoting the Council's Committee on the Elimination of Waste in Industry in regard to cyclical depressions. It was Mr. Hoover's plan that parts of the investigation which he suggested fall in the same general field as that explored by the Waste Committee.

The Council recommended that as large a measure of assistance as possible be rendered to Mr. Hoover, who started the nationwide engineering assay of waste. The survey of industry which has just been started will come up for discussion at the next meeting of the Council's executive board to be held in Pittsburgh in May.

The report of the Council's Waste Committee, which revealed huge losses to the country through avoidable waste, has, Mr. Wallace said, exercised an enormous influence throughout the country, and is being taken up by hundreds of commercial and civic bodies, by universities and individuals in an effort to rid industry of losses, which the investigators found ran into the billions. Foreign countries also are manifesting a lively interest in the findings, and in the new republic of Czechoslovakia the government is officially sponsoring the distribution to all the industries of a translated version of the report of the committee.

Research bodies and individuals, including members of the Unemployment Conference, have agreed to cooperate in the general study of business depression that will be made by Secretary Hoover and his aids. Other organizations that have agreed to lend their cooperation are the U. S. Chamber of Commerce, the Department of Labor, Bureau of Railroad Economics, Russell Sage Foundation, Harvard Committee on Economic Research, American Association of Labor Legislation, Pennsylvania State Industrial Board and the National Bureau of Economic Research.

COMMITTEE APPOINTMENTS

Appointments to various committees of the American Engineering Council have been confirmed by President Mortimer E. Cooley. The personnel of these committees now consists of the following:

STANDING COMMITTEES

Committee on Procedure. M. E. Cooley, chairman. Calvert Townley, Dexter S. Kimball, J. Parke Channing, W. E. Rolfe, W. W. Varney, and H. E. Howe.

Finance Committee. H. E. Howe, chairman; Calvert Townley, C. H. MacDowell, W. S. Lee, and W. J. Fisher.

Committee on Public Affairs. J. Parke Channing, Lewis B. Stillwell and Arthur M. Greene, Jr.

Committee on Membership and Representation. O. H. Koch and L. B. Smith.

Committee on Constitution and By-Laws. W. B. Powell, chairman; C. F. Scott and Joseph W. Roe.

Committee on Publicity and Publications. L. P. Alford, L. F. Morehouse and Paul Wright.

SPECIAL COMMITTEES

Forestry Committee. W. B. MacDowell, chairman; W. H. Hoyt, C. J. Ralston, S. H. McCrory, and Charles R. Gow.

Committee on Affiliations with Engineering Societies Outside of the U. S. A. Gardiner S. Williams, chairman; J. Parke Channing, Calvin W. Rice, F. F. Sharpless, and F. L. Hutchinson.

Foreign Relations Committee. J. Parke Channing, chairman; C. T. Main, F. S. Cottrell, J. W. Lieb, P. N. Moore, J. R. Freeman, L. B. Stillwell, and C. A. Mailloux.

New York State Government Reorganization Committee. H. de B. Parsons, chairman; Paul G. Brown and L. B. Stillwell.

Engineering Education Committee. W. W. Varney and C. F. Scott (Chairman to be appointed to succeed A. S. Dwight, resigned).

Regional Activities Committee. Gardiner S. Williams, chairman; W. B. Powell, W. J. Fisher, Paul Wright, Lloyd B. Smith, O. H. Koch, J. C. Ralston and James R. Withrow.

Committee on Employment. (Personnel to be announced later).

PERSONAL MENTION

Charles E. Cansfield, formerly with the Toronto & Niagara Power Company, has opened an office in Toronto for the practise of electrical engineering.

E. F. Du Rieu, of the General Electric Company, Schenectady, N. Y., has left for Australia where he will be located with the Australian General Electric Company, Melbourne.

A. R. Nissar, Electrical Engineering Dept., Central Technological Institute, Bombay, India, has been elected secretary of the Bombay Association of the Institution of Engineers, India.

Carl C. Long, until recently electrical engineer with Riegos y Fuerza del Ebro, Barcelona, Spain, is now in the engineering department of the Southern California Edison Company, Los Angeles, Cal.

W. Keith McAfee has become connected with The Universal Sanitary Manufacturing Company, New Castle, Pa., as engineer. He was formerly with the Pennsylvania Railroad Company, New York City.

Edwin T. Williams has recently become located with the Insulation & Specialty Corporation of America, New York City, as plant engineer. He was previously engineer with Groton Electrical Devices, Inc., Groton, N. Y.

Ernest N. Calhoun, formerly connected with The Cutler-Hammer Manufacturing Company as sales engineer, has been appointed sales manager of the electrical heating department of the Edwin L. Wiegand Company, Pittsburgh, Pa.

James C. Webster has accepted a position as brush engineer with the Canadian National Carbon Company, Ltd., Toronto, Ont. He was previously with the National Carbon Company, Inc., Cleveland, O., in the capacity of chemical engineer.

P. O. Reyneau, who has been connected with the Detroit Edison Company for a number of years, has recently resigned from that company to accept appointment as superintendent of the designing and estimating divisions of the transmission and distribution departments of the Philadelphia Electric Company.

W. M. Holmes has recently returned to the Southern California Edison Company in the capacity of electrical engineer, having been away more than four years during which time he served in the Bureau of Steam Engineering in the Navy, at Chicago and San Francisco, and in the Standard Oil Company in Bakersfield, Cal.

Dugald C. Jackson, professor of electrical engineering in the Massachusetts Institute of Technology, and consulting engineer of Jackson & Moreland, Boston, was recently elected president of the Boston Society of Civil Engineers. Prof. Jackson is a Fellow of the A. I. E. E., and served as president during the year 1910 to 1911.

Clarence G. Spencer, recently on the consulting board of the American Sugar Refining Company, New York, N. Y., is now connected with McClellan & Junkersfeld, Inc., of New York City. This firm was recently incorporated by William McClellan, Peter Junkersfeld, and Horace T. Campion, to carry on engineering and construction work.

N. C. Husted has resigned his position with Hubbard & Company, Pittsburgh, to become associated with the recently organized Seyler Manufacturing Company of Pittsburgh. Mr. Seyler, president of this company, was formerly with Hubbard & Company as vice-president and general manager. Mr. Husted will be sales engineer of the Seyler Company.

W. T. Blackwell, for the past four years manager of the illuminating engineering bureau of the Westinghouse Lamp Company, New York City, has recently left to become connected with the Westinghouse Electric & Manufacturing Company, George Cutter Works, South Bend, Ind. He will be manager of the interior lighting division of the George Cutter Company.

Mark Eldredge has been appointed assistant manager of the Ludlow Jute Company's mills, Calcutta, India. Mr. Eldredge first went to India in 1911 as professor of electrical engineering, Ewing College, Allahabad, and later joined the Tata Hydroelectric Power Supply Company, Bombay. During the war he served in the Construction Division of the United States Army, resigning after the war to return to India, where he has been superintendent of power with the Ludlow Jute Company, Ltd.

Harrison P. Reed, for many years electrical engineer and more recently in charge of the elevator department of the Cutler-Hammer Manufacturing Company of Milwaukee and New York, has resigned to become general manager of the A. Kieckhefer Elevator Company of Milwaukee. Mr. Reed has had wide experience in elevator work, and has been a frequent contributor to engineering publications. He is a Fellow of the Institute, and is at present a member of the Industrial and Domestic Power Committee, being chairman of the Sub-Committee on Electric Elevators.

Harry W. Osgood has joined the engineering department of McClellan & Junkersfeld, Inc., New York, as Electrical Engineer. Mr. Osgood was with Stone & Webster, Inc., fourteen years, and has had a varied experience in design and construction of power plants and distribution systems and other engineering work for public utility and industrial companies. In 1917 he was assigned by Stone & Webster to the American International Shipbuilding Corporation as electrical engineer for the design and construction of the Hog Island Shipyard at Philadelphia. Following this in 1919 he became electrical engineer for plant construction for the Bethlehem Shipbuilding Corporation, at Bethlehem, Pa.

Obituary

Charles A. Rohr, of the General Electric Company, New York City, died suddenly on March 27, 1922, following overexertion while playing a game of squash at his athletic club in Brooklyn, N. Y. Mr. Rohr had been warned by his physician against taking violent exercise, but insisted upon playing the game of squash, to which he had been devoted since his college days. Mr. Rohr was born in St. Louis, June 19, 1890, and was graduated from Cornell University, class of 1911, with the degree of M. E. He entered the employ of the General Electric Company immediately following his graduation, and had remained with that company since in various capacities. He joined the Institute in 1914.

John Fay Wilson, professor of electrical and mechanical engineering at the University of Southern California, died on February 15, 1922. Mr. Wilson was born in Bellflower, Ill., his family soon after moving to Kansas, where he attended school and received a B. S. degree from the University of Kansas. He was then engaged for several years in electrical engineering work, particularly designing engineering. In 1911 he became a teacher in the college of engineering of the University of Michigan, continuing there for five years. During 1916-1917 he was professor of electrical engineering at Queen's University, Kingston, Ont., and in 1917 went to the University of Southern California, where he remained until the time of his death, although in poor health. Prof. Wilson was the author of two text-books which have been used extensively, one on "Essentials of Electrical Engineering," and the other a "Manual of Laboratory Practise." Thoroughly familiar with advanced theoretical subjects in electrical engineering, he was a competent teacher and secured the interested cooperation of his pupils. He joined the Institute in 1907.

Richard Pfund. The Institute has just received word of the death several months ago of Mr. Richard Pfund in New York City. Mr. Pfund, prominent in telephone and radio engineering, had retired in 1913, but took up active work again during the war as expert radio aide at the League Island Navy Yard. He then remained with the Government, and at the time of his death was connected as radio engineer with the Signal Corps, 8th Corps. Area, with headquarters at Fort Sam Houston, Tex. In the early part of his career Mr. Pfund was connected for many years with the Western Union Telegraph Company. Shortly after Marconi's first experiments with Herzian wave telegraphy, Mr. Pfund affiliated himself with the American Marconi Company. Later he led the first and second Alaskan expeditions of the Signal Corps for the purpose of installing spark-coil and coherer sets along the Tanana River, and subsequently joined the forces of the Telefunken system as chief engineer and general manager, as such introducing the first quenched spark gap in America. Under his guidance the Telefunken system opened up the interior Brazil territory from Para to Manaos and farther up the Amazon River. Mr. Pfund was one of the early members of the Institute, of which he became an Associate in 1893, and received a transfer to the grade of Member in 1913.

Leo Daft, one of the pioneers in the electric railway field and a member of the Institute since December 9, 1884 died on March 28, 1922 at the Albany Hospital.

Mr. Daft was born at Birmingham, England, November 13, 1843; his father being Thomas B. Daft, a prominent civil engineer. In 1859 Mr. Daft entered London University, as a special student in civil engineering, and at this time became acquainted with Sir William Siemans who aided him in carrying out his electrical experiments. He came to the United States in 1866 and first engaged in railroad engineering in connection with some extensions of the Louisville and Nashville Railroad, then in course of construction. His first venture in the electrical field was with the New York Electric Light Company, which was soon merged in the Daft Electric Co. The company was almost exclusively devoted to the development of electric power machinery, and established several power stations in Boston, New York, Worcester and elsewhere.

In 1883 Mr. Daft built an electric locomotive named the "Ampere" for use on the Saratoga and Mt. McGregor Railroad and in the following year installed short lines at Coney Island and elsewhere. On August 9, 1883 he put into operation what was probably the first electric elevator in the world, at the Garner Cotton Mills, Newburgh, N. Y. In 1884 he supplied the machinery for the New York Power Company's Gold Street Station. In 1885 he furnished electrical equipment for a branch of the Baltimore Union Passenger Railway Co. This road was one of the first commercially operated in the United States. In recent years Mr. Daft directed his attention principally to the electrochemical field, having invented a process, whereby rubber can be vulcanized directly on to metal, making a bond having a greater tensile strength than the rubber itself.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 6 p. m.

FATIGUE OF METALS

An investigation of the fatigue of metals has been conducted by the Engineering Experiment Station of the University of Illinois in cooperation with the National Research Council, the Engineering Foundation and later, the General Electric Company. A report of the investigation by H. F. Moore and J. B. Kommers has been published as Bulletin No. 124 of the Engineering Experiment Station. It gives a detailed account of the conditions under which the tests were made, illustrates by figures and tables the results of the tests and outlines subjects for further investigation. A bibliography with 132 author entries accompanies the report.

A series of tests in the British National Physical Laboratory in which the "rise of temperature" test is shown to give a fairly accurate measure of the endurance limit is noted as appearing after the preparation of the manuscript of this bulletin. These tests were made by H. J. Gough and were reported in *The Engineer*, Aug. 12, 1921. A preliminary paper "On the Inter-Crystalline Fracture of Metals under Prolonged Application of Stress," by Walter Rosenhain appears in the Collected Researches of the National Physical Laboratory, Vol. 15, 1920, reprinted from the *Proceedings of the Royal Society*, A, Vol. 96, 1919, and as the investigation continues it may be of interest in connection with this subject.

Bulletin 124 may be obtained from the Engineering Experiment Station, University of Illinois. It is now on file in the Engineering Societies Library, both in the reference and the loan collection.

BOOK NOTICES (MARCH 1-31, 1922.)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or text of the book.

All the books listed may be consulted in the Engineering Societies Library.

Course in Electrical Engineering. Vol. 2. Alternating Currents.

By Chester L. Dawes. First edition. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. (Electrical Engineering texts.) 526 pp., illus., 8 x 6 in., cloth. $4.00.

An elementary text-book intended as an introduction to more advanced books. Prepared for students who have such a knowledge of direct currents as is given by volume one of this work, but with no previous study of alternating currents.

ECONOMICS OF ELECTRICAL DISTRIBUTION.

By P. O. Reyneau and H. P. Seelye. First edition. N. Y. and Lond., McGraw-Hill Book Co., Inc., 1922. 209 pp., charts, 9 x 6 in., cloth. $2.50.

In designing, constructing or operating an electrical distribution system, the object to be sought is to provide all customers with good service at the least possible cost over the system as a whole. This result can be attained only by a careful application of economic principles to all parts of the system. This book defines these principles and indicates methods for their application. Attention is called to the need for economic study in design, the fundamental principles are explained, the usual types of problems are indicated and methods of studying them offered.

ELECTRIC ARC WELDING.

By E. Wanamaker and H. R. Pennington. N. Y., Simmons-Boardman Publishing Co., 1921. 254 pp., illus., 9 x 6 in., cloth. $4.00.

This manual is based largely on a series of articles published in the *Railway Electrical Engineer*. It contains a large amount of practical information on many phases of the subject; descriptions of systems and their installation, phenomena of metallic and carbon welding arcs, training of welders, sequence of metal deposition for various types of joints and building-up operations, electrodes, thermal disturbances due to welding, properties of welds, efficiency of equipments and costs. The book is confined to autogenous arc welding.

ELECTRIC SHIP PROPULSION.

By S. M. Robinson. N. Y., Simmons-Boardman Publishing Co., 1922. 274 pp., illus., diagrs., 9 x 6 in., cloth. $6.00.

This volume treats of the special questions relating to steam turbines, electric generators, induction motors and other machines, which arise in connection with the propulsion of ships by electricity, and compares this method with others. The various systems are explained and compared. The installations on several ships of the Navy and on the *Wulsty Castle*, which illustrate the application of various systems, are described in detail.

IONS, ELECTRONS, AND IONIZING RADIATIONS.

By James Arnold Crowther. Third edition. N. Y., Longmans, Green & Co.; Edward Arnold, 1922. 292 pp., diagrs., 9 x 6 in., cloth. $4.00.

This edition has been thoroughly revised and new matter has been added wherever necessary. It now includes the results of recent work on constants, a fuller account of positive rays, and an account of the nuclear theory of the atom. The book is intended to be a reasonably complete account of the present state of the subject, suitable for students who wish a systematic knowledge of the late developments in physics.

ELEMENTS OF THE INFERENTIAL AND INTEGRAL CALCULUS.

By William S. Hall. Second edition, revised. N. Y., D. Van Nostrand Co., 1922. 250 pp., 9 x 6 in., cloth. $2.75.

This text-book is an endeavor to present the calculus and some of its important applications simply and concisely, yet fully enough to make possible the study of subjects that call for knowledge of it. In this new edition chapters 1, 4 and 5 have been rewritten, other revisions have been made and many new problems added.

MATHEMATICAL PHILOSOPHY.

By Cassius J. Keyser. N. Y., E. P. Dutton & Co., 1922. 466 pp., 8 x 6 in., cloth. $4.70.

This course of lectures by the Adrian Professor of Mathematics at Columbia University aims to disclose fundamental connections between mathematics and philosophy. The author attempts to give an insight into the essential nature of mathematics regarded as a distinctive type of thought, to show what is characteristic and fundamental in mathematical method, acquaint readers with those of the great mathematical concepts that are available to laymen, and thus to give an understanding of mathematics in relation to the other sciences and arts.

REAL MATHEMATICS.

By Ernest G. Beck. Lond., Henry Frowde and Hodder & Stoughton. 1922. (Oxford technical publications.) 306 pp., diagrs., 8 x 5 in., cloth. 15s. (Gift of Oxford University Press, American Branch.)

This book is intended to assist in the acquisition of a real, serviceable, sound mathematical equipment by augmenting standard text-books and orthodox methods of study. The author hopes it will contribute toward the adoption of a change of attitude toward mathematics by those who require it as a part of their working equipment, by showing it as an actual, tangible reality, instead of a collection of rigid and unrelated rules and formulas. The method given assists the stdent out visualize the various operations and processes used in mathematical calculation.

L'ETHER ACTUEL ET SES PRECURSEURS.

By E. M. Lemeray. Paris, Gauthier-Villars et Cie, 1922. (Actualites scientifiques.) 141 pp., 7 x 5 in., paper.

The author of this book, an early student of the investigations of Lorentz and Einstein, is a master of theories of relativity and has written several summaries of them. In the present work he traces the development of the idea of the ether, which these theories tend to modify anew.

The book is the result of an extensive examination of the history of science. Beginning with the ideas of the Chaldeans and Egyptians concerning a universal spirit, the modifications due to the Greeks and Romans, the ether of Huyghens, phlogiston, caloric, the ether of Fresnel and that of later students are described.

AGGREGATION AND FLOW OF SOLIDS.

By Sir George Beilby. Lond., Macmillan and Co., Ltd., 1921. 256 pp., plated, 9 x 6 in., cloth. 20s.

The molecular structure and physical properties of matter in the solid state have engaged the author's attention for many years, and from time to time papers embodying the results from particular researches have been published. The entire series of investigations has now been collected and sifted, and the results appear in the present volumes as a consecutive whole.

The book is an interesting record of actual experimental observations, many of which have important industrial applications, and a summary of the conclusions reached by the author as to the meaning of the phenomena observed. A large number of excellent photo-micrographs is included.

DYNAMIC AND STATIC BALANCING.

By Edward K. Hammond. First edition. N. Y., Industrial Press; Lond., Machinery Publishing Co., Ltd., 1921. 58 pp., illus., 8 x 6 in., paper. $.50.

A discussion of the principles of balancing, with a description of machines and methods, written in simple language. Intended for shop men. Avoids mathematical theory.

COMPREHENSIVE TREATISE ON INORGANIC AND THEORETICAL CHEMISTRY.

By J. W. Mellor. Vol. 1-2. London and N. Y., Longmans, Green and Co., 1922. 2v. illus., 10 x 6 in., Cloth. $20.00 a vol.

Mellor's Comprehensive Treatise aims, when completed, to give a complete description of all the compounds known in inorganic chemistry and, where possible, to discuss them in the light of physical chemistry.

Volume one is mainly introductory. It treats of the evolution and methodology of chemistry, of chemical combination, atoms, molecules, and hydrogen and oxygen and their compounds. The second volume includes the halogens, the alkali metals and ammonium compounds.

Subjects are treated with great fullness. Authorities are given for all statements of fact. The references to original publications are very complete.

The work fills an important gap in modern chemical literature and will be a necessity, not only to chemists, but to workers in the various chemical and metallurgical industries who have use for precise data concerning chemical elements and compounds. No work of similar character and completeness exists in the English language.

INTRODUCTION TO PHYSICAL CHEMISTRY.

By Sir James Walker. Ninth edition. Lond., Macmillan and Co., Ltd., 1922. 438 pp., illus., 9 x 6 in., cloth. $4.50. (Gift of the Macmillan Co., N. Y.)

Intended for the student with some knowledge of chemistry and physics who wishes a work that will effect a connection between the knowledge which he possesses and the works on physical chemistry. By selecting certain chapters of physical

chemistry and treating the subjects contained in them at some length with a constant view to their practical application, this book is arranged to serve as an explanatory introduction.

The present edition is revised and partly rewritten.

PRACTICAL CHEMISTRY OF COAL AND ITS PRODUCTS.

By A. E. Findley and R. Wigginton. London, Benn Brothers, Limited, 1921. 144 pp., diagrs., tables 9 x 6 in., cloth. 12s. 6d.

A collection of reliable methods for analyzing coal, coke, ammonia liquor, benzene, coal tar, water, gas, and similar products and raw materials of the gas and coke industries. Based on the course in fuel technology at Sheffield University.

DISTRIBUTION OF GAS.

By Walter Hole. Fourth edition. London, Benn Brothers, Limited, 1921. 699 pp., illus., diagrs., 10 x 7 in., cloth. 50s.

This book is uniform in size with Meade's "Modern Gasworks Practise" to which it forms a fitting companion. That work treats of gas manufacture, this takes up the account of the gasholder and discusses the distribution to the consumers' appliances.

The scope of the volume is a wide one. The opening chapter discusses the rights and duties of gas undertakings. Succeeding chapters treat of discharges from pipes, station governors, districting, pipes and joints of iron and steel, mainlaying, valves and cocks, conduits, service pipes, meters, internal fittings, internal lighting, gas stoves and heaters, gas engines, industrial uses of gas, pressures, complaints and repairs, street lighting, high-pressure distribution, high-pressure lighting and heating, leakage, electrolysis and fusion. The information given is thoroughly representative of current practise. Obsolete matter has been deleted in preparing this new edition and much that is new has been added.

MODERN GASWORKS PRACTISE.

By Alwyne Meade. Second edition. London, Benn Brothers, Limited, 1921. 815 pp., illus., diagrs., 10 x 7 in., cloth. 55s.

The first edition of this book appeared in 1917 and quickly became out of print, through the immediate recognition of its worth as the most complete, authoritative account of modern practise extant. The new edition, while retaining all the merits of the first, has undergone an increase in bulk of 50 per cent, through the addition of new matter, and has also been largely rewritten, to take account of the upheaval in the technique of gasworks practise in England, caused by the substitution of a calorific standard for the former candle power standard.

Every phase of the works side of gas engineering is covered, from the planning and construction of gasworks to the storage of the gas and recovery of the by-products. As a general work of reference, the book is of the greatest value to all engaged in the gas industry.

HEATING AND VENTILATION.

By John R. Allen and J. H. Walker. Second edition. N. Y. and Lond., McGraw-Hill Book Co., Inc.; 1922. 332 pp., illus., diagrs., tables, 9 x 6 in., cloth. $3.50.

A text-book for use in engineering and architectural schools, intended also for use as a handbook by engineers and architects. A second edition has become desirable because of the advances in the art made recently such as the establishment of standards for ventilation and the results obtained in the research laboratory of the American Society of Heating and Ventilating Engineers. The text has been thoroughly revised and enlarged to include recent developments.

MANUAL OF STANDARD PRACTISE FOR THE POWER LAUNDRY WASHROOM.

By the Industrial Fellowship of the Laundryowners National Association. La Salle, Ill., Laundryowners National Association, 1922. 112 pp., 8 x 5 in., paper. $1.00.

For several years the Chemical Engineering Department of the Laundryowners National Association has been engaged, in cooperation with the Mellon Institute of Industrial Research, in an investigation of laundry practise. The present volume is a report of the results attained. It presents a clear statement of the best practise in the washroom, gives standard formulas for proper procedure and discusses the supplies used in the work.

OPERATING ENGINEER'S CATECHISM OF STEAM ENGINEERING.

By Michael H. Gornston. N. Y., D. Van Nostrand Co., 1922. 428 pp., diagrs., 8 x 5 in., fabrikoid. $4.00.

An elementary text-book upon the construction and operation of boilers, steam engines and turbines, heating apparatus and pumping machinery, prepared for operating engineers. Covers the problems that confront the engineer with unusual fullness and is well indexed. Should be of assistance to those preparing for examination and as a pocket reference book.

QUESTIONS AND ANSWERS RELATING TO DIESEL, SEMI-DIESEL, AND OTHER INTERNAL-COMBUSTION ENGINES; AIR COMPRESSORS, ETC.

By John Lamb. Lond., Charles Griffin & Co., Inc.; Phila., J. B. Lippincott Co., 1922. 209 pp., 4 x 5 in., cloth. 5s.

A small pocketbook of practical information for steam engineers and others preparing for license examinations.

BLUE PRINTING AND MODERN PLAN COPYING.

By B. J. Hall. London and N. Y., Sir Isaac Pitman & Sons, Ltd., 1921. 130 pp., illus., 8 x 5 in., cloth. $2.00.

Of interest to engineers who have plans to be copied, to installers of copying plants and to operators. The first section of the book discusses the capabilities of contact photography and allied processes for copying drawings, as well as the proper preparation of drawings for reproduction. Section two describes the machinery and apparatus used in blue printing plants. The concluding section deals with the layout of blue-printing rooms and methods of working. Both contact and camera processes are included.

FACTORY ADMINISTRATION IN PRACTISE.

By W. J. Hiscox. Lond. and N. Y., Sir Isaac Pitman & Sons, Ltd., 1921. 214 pp., 9 x 6 in., cloth. $2.50.

Most of the books on factory administration seem to have been written by accountants for accountants, our author thinks, and as a consequence have disregarded factory conditions to some extent. The present work is written from the factory viewpoint, and is intended for the works manager, the foreman and all members of the factory administrative staff. The views and schemes set forth are the results of sixteen years' practical experience with engineering firms in Great Britain. Special prominence is given to the progress system.

SAN FRANCISCO BAY MARINE PILING SURVEY.

Second annual progress report. San Francisco, The Committee, 1922. 82 pp., plates. 9 x 6 in., paper.

During 1921, the approximate period covered by this report, attention has been directed to compiling service records for existing structures and preparing a standard form for service reports, to studying methods of construction and protection and to a biological study of the destructive agency, Teredo navalis. Advice upon proper methods of handling and using piling, repairing, creosoting, etc., is given accompanied by specifications for creosoted piling and lumber.

Addresses Wanted

A list of members whose mail has been returned by the Postal Authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th Street.

1.—Eugene A. Baerer, Box 253, Kenvil, N. J.
2.—Waldo C. Cole, 410 Mills Bldg., El Paso, Texas.
3.—O. A. Darnell, 409 East 5th St., Los Angeles, Calif.
4.—E. W. Erikson, 214 University Club Bldg., St. Louis, Mo.
5.—Victor R. Fisher, U. S. Submarine Base, Coco Sola, Canal Zone.
6.—Leonard Knowles, 411 South 56th St., Philadelphia, Pa.
7.—Wen Siang Lu, Y. M. C. A., Lynn, Mass.
8.—Thos. H. McCauley, New Brunswick Power Co., St. John, N. B.
9.—C. B. Rice, 125 East 37th St., New York, N. Y.
10.—Lee R. Scott, 158 Gibbs St., Rochester, N. Y.
11.—R. W. Seem, 633 West 74th St., Los Angeles, Calif.
12.—J. Herbert, Shanhan, 527 Morris Ave., Elizabeth, N. J.
13.—D. Boyd Smith, Box 813, McGill, Nevada.
14.—F. W. Smith, 500 Todd St., Wilkinsburg, Pa.
15.—Theo. V. Tillinghast, c/o Plano Toy Co., Plano, Ill.
16.—Louis H. Wessels, 105 Union St., Jersey City, N. J.

Past Section and Branch Meetings

PAST SECTION MEETINGS.

Akron.—March 22, 1922, Engineers Society of Akron Rooms. Paper: "Industrial Lighting." Author: Mr. A. R. Holden, of the B. F. Goodrich Company, Akron, O. Lantern slides were shown and an interesting discussion followed. Attendance 22.

Atlanta.—March 30, 1922, Y. M. C. A. Auditorium, Georgia School of Technology. Subject: "Steam Turbines," illustrated by lantern slides. Speaker: Mr. E. F. McLaughlin, steam turbine expert, of the General Electric Company. A very interesting moving picture, showing the construction of a fifty thousand kw. unit, was also shown. Attendance 30.

Baltimore.—March 17, 1922, Engineers Club. Subject: "The Relation of the Bureau of Standards to the Industries of the Country." Speaker: Dr. S. W. Stratton, director of the Bureau of Standards. Attendance 35.

April 7, 1922, Mechanical Engineers Building, Johns Hopkins University. Subject: "The Elements of Radio Practise." Speaker: Mr. W. G. Brombacher, instructor in physics, Johns Hopkins University. Refreshments were served. Attendance 190.

Boston.—March 14, 1922, Lorimer Hall. Subject: "Sectionalized Paper Machine Drive." Speaker: Mr. H. W. Rogers, of the General Electric Co. The paper was thoroughly illustrated with lantern slides and the various points of difficulty in handling the paper machine in sections by separate electric motors were brought out. Attendance 70.

Chicago.—March 21, 1922, Rooms of Western Society of Engineers. Joint meeting with the Western Society of Engineers. Ladies were invited to attend. Subject: "Opportunities for Engineers." Speaker: Mr. John W. O'Leary, vice-president of the Chicago Trust Company. Attendance 200.

March 22, 1922, Rooms of Western Society of Engineers. Midwinter Convocation of Engineers, conducted jointly with all of the Chicago Engineering Societies, for the purpose of discussing the current engineering problems within the City of Chicago. The general subjects discussed were: Sewage Treatment, Public Utilities, City Planning, Transportation (all kinds), and the Great Lakes—St. Lawrence Waterway. The meeting was called at 9:30 a. m. and lasted throughout the day. Average attendance 180.

Cincinnati.—March 16, 1922, Literary Club Rooms. Joint meeting with the Engineers' Club. Subject: "The Respective Fields of the Rail Car, the Trolley Bus and the Gasoline Bus in City Transportation" (illustrated). Speaker: Mr. J. C. Thirwall, engineer, railway department of the General Electric Company. The subject was commented upon and discussed by Mr. T. H. Schoepf, Vice-President of the Cincinnati Traction Company. Attendance 125.

April 6, 1922, University of Cincinnati. Subject: "The Rise and Fall of the Electric Systems." Speaker: Mr. B. G. Lamme, chief engineer, Westinghouse Electric and Manufacturing Company. The meeting was also addressed by Mr. N. W. Storer, vice-president of A. I. E. E. Geographical District No. 2, and Mr. P. M. Lincoln, a past-president of the A. I. E. E. Attendance 175.

Cleveland.—March 21, 1922, Ball Room, Hotel Winton. Joint meeting with Cleveland Section, American Chemical Society. The meeting was preceded by a well attended dinner. Subject: "The Geography of Electro-chemistry." Speaker: Dr. W. S. Landis, chief technologist of The American Cyanimid Company. Attendance 125.

Connecticut.—February 13, 1922, Hartford Club, Hartford, Conn. Subject: "The Key to Future American Development." Speaker: Dr. William McClellan, president A. I. E. E. Attendance 35.

Denver.—March 18, 1922, Adams Hotel. Mr. Lawrence Phipps, Jr., presented four films on the power system of the Nevada-California Electric Corporation, and many of the companies throughout that district which the corporation serves with various classes of electrical service. A film on the structure of the atom, belonging to the General Electric Company, was also shown. Attendance 25.

Erie.—March 14, 1922, Community House. Joint meeting with the Engineers Society of Northwestern Pennsylvania. Subject: "The Creative Workman." Speaker: Mr. Robert B. Wolf. Attendance 105.

March 21, 1922, Erie Public Library. Subject: "Electrochemistry." Speaker: Mr. B. F. Swartz. Attendance 20.

Fort Wayne.—March 16, 1922. The members met in a body at the interurban station at 7:30 p. m. and filled a special car which was provided by the traction company. The first part of the trip took the party to the Decatur substation, where during a short shut-down period Mr. W. S. Richhart described and explained the operation of the various pieces of the automatic equipment. After observing the station start under normal load conditions the members were taken to the new manual substation at Webster and Melita Streets, Fort Wayne. The inspection of the equipment in this station completed the trip. The Entertainment Committee kept the members supplied with cigars and cigarettes. Attendance 70.

March 20, 1922, G. E. Co. Bldg. No. 16. Business meeting for the purpose of voting on amendments to the By-laws. Attendance 22.

Indianapolis-Lafayette.—March 17, 1922. Palm Room, Claypool Hotel. Subject: "Respective Field of Rail Car, Gasoline Bus and Trolley Bus," illustrated by motion pictures showing the trolley bus in actual operation. Speaker: Mr. J. C. Thirlwall, of the Railway Department, General Electric Company. Attendance 68.

Ithaca.—March 24, 1922, Franklin Hall, Cornell University. Subject: "Corona Loss and Insulator Testing at 600,000 volts." Speaker: Professor C. Francis Harding, of Purdue University. Attendance 70.

Kansas City.—March 24, 1922, University Club. Radio Concerts, broadcast by Kansas City Star and Kansas City Post. Subject of paper presented: "Industrial Application of Power" (illustrated by lantern slides). Speaker: Mr. G. S. Dewey, of the Kansas City Power and Light Company. Buffet lunch was served. Attendance 48.

Lehigh Valley.—March 9, 1922. Previous to the meeting an informal dinner was held at the Easton Y. M. C. A., with Messrs. N. W. Storer, vice-president of Geographical District No. 2, and C. W. Horn, speaker of the evening, as guests of honor. The evening session was held at Pardee Hall, Lafayette College, Easton. Subject: "Radio Telephony and Broadcasting" (illustrated). Speaker: Mr. C. W. Horn, of the Westinghouse Electric & Manufacturing Company, E. Pittsburgh, Pa. The paper was accompanied by interesting demonstrations, and by means of a loud speaking attachment the audience was entertained with speeches, music and singing picked up from the nearest broadcasting stations within the range of Easton. Attendance 350.

Los Angeles.—March 28, 1922, Assembly Room, Edison Building. Mr. R. H. Cates, Power Engineer, of the Southern California Edison Company, gave a short history of irrigation on the whole, and then more specifically on irrigation by means of pumping, showing several curves of the performance of different kinds of pumps under different conditions. Attendance 62.

Lynn.—March 15, 1922, G. E. Hall. Subject: "The Nature of Tribo-Electricity of Friction and other Kindred Matters." Speaker: Professor Elihu Thomson. Attendance 200.

Milwaukee.—March 22, 1922, Milwaukee Athletic Club. Meeting of Engineers' Society of Milwaukee, under the auspices of the American Association of Refrigerating Engineers. Before the presentation of the paper Mr. R. E. Stoelting, of the Milwaukee City Planning Commission, gave an interesting talk on the Milwaukee Civic Center plan and the future development of the city. Paper of the evening: "The Fundamental Principles of Refrigeration." Speaker: Mr. W. H. Motz. Attendance 150.

Minnesota.—March 27, 1922, Elks' Club, St. Paul. A dinner was served immediately preceding the meeting. Subjects: "Synchronous Motors and Power Factor Correction" by Mr. J. H. Kuhlman, of the University of Minnesota, and "Static Condensers" by Mr. B. E. Ward, of the General Electric Company, Chicago, Ill. Both papers were illustrated by lantern slides. Attendance 60.

New York.—On the evening of Friday, April 14, 1922, a joint meeting of the New York Section of the A. I. E. E. and the Metropolitan sections of the A. S. M. E. and A. I. M. E. was held in the auditorium of the Engineering Societies Building, 33 West 39th St., New York. The subject of the evening was "Muscle Shoals as a Power and Nitrate Producer." The meeting which was attended by almost 900 engineers was opened by W. S. Finlay, Jr. who introduced Theodore Nagel, consulting engineer. Mr. Nagel briefly outlined the various processes carried on at the plant leading to the ultimate product, the high explosive, ammonium nitrate. Motion pictures of the entire plant and its equipment were then shown and explained by him. Brigadier General Harry Taylor, Asst. Chief of Engineers, U. S. A. then described "Muscle Shoals as a Power Producer." He was followed by W. S. Landis, Chief Technologist, American Cyanamid Co., who detailed the various processes taking place at the plant in the manufacture of high explosive and called attention to the inability to economically alter the plant for the making of fertilizer on a business basis, unless subsidized. Major General C. C. Williams, Chief of Ordnance, U. S. A. then spoke on the Muscle Shoals question from the viewpoint of Munitions. He pointed out the necessity of maintaining plants capable of producing explosives in the quantities called for by modern warfare and doing so without delay as under ordinary conditions armies could be placed in the field before explosives could be furnished, making it necessary to have a considerable surplus always on hand to bridge the interim. Discussion was led by Francis E. Frothingham, of Coffin & Burr, Bankers, and E. A. Yates of Wood, Hulse & Yates Co., Engineers.

Directly preceding the technical session, Farley Osgood, Chairman of the A. I. E. E. Section announced the election of officers for the coming year, as follows: *Chairman*, Calvert Townley of the Westinghouse Elec. & Mfg. Co., *Secretary-Treasurer*, Alfred E. Waller, Ward-Leonard Electric Co.; *Executive Committee*, Frederick M. Feiker, McGraw-Hill Co., and H. C. Carpenter, New York Telephone Co.

Oklahoma.—March 22, 1922, World Building, Tulsa, Oklahoma. Organization meeting and election of officers as follows: Chairman, Fred W. Insull; Vice-Chairman, Ernest E. Hunter; Secretary-Treasurer, A. D. Stoddard. Adoption of By-laws. Attendance 13.

Philadelphia.—February 28, 1922, Manufacturers' Club of Philadelphia. Symposium on Textile Manufacture and Economics, held under joint engineering and textile auspices. Subjects: "Worsted Manufacture" by W. D. Hartshorne, Lawrence, Mass.; "Cotton Manufacture" by Sidney B. Paine, Boston, Mass.; "Problems and Economics of the Textile Power Plant" by Leo Loeb, of Day & Zimmerman, Philadelphia; "Mechanical Handling of Materials in Textile Plants" by Charles M. Mumford, Boston, Mass. Motion Pictures: "A Woolen Yarn" (1 reel) and "In the Land of Cotton" (2 reels), shown through courtesy of General Electric Company, Schenectady, N. Y. Attendance 700.

March 15, 1922, Franklin Institute. Subject: "Recent Progress in Applied Electrochemistry." Speaker: Mr. M. De Kay Thompson, Ph. D. Previous to the meeting an informal dinner was held at the Engineers' Club, Philadelphia, in honor of the speaker. Attendance 150.

March 21, 1922, Manufacturers' Club. Hydroelectric Conference. *Afternoon Session.* Subjects: "The Relation of Water Resources to the Country's Development" by Nathan C. Grover, U. S. Geographical Survey; "The 55,000-Horse Power Turbines for the Queenston-Chippawa Development" (illustrated), by Frank H. Rogers, The William Cramp & Sons Ship & Engine Building Company, Philadelphia; "Salt Velocity Method of Measuring Water in Pipe Lines" (illustrated), by Charles M. Allen, Worcester Polytechnic Institute; "The Correlation of Momentum and Energy Changes in Steady Flow with Varying Velocity and the Application of the Former to Problems of Unsteady Flow or Surges, in Open Channels" (illustrated), by Raymond D. Johnson, Consulting Engineer, New York City; "The Hydraulic Turbine in Evolution" (illustrated), by H. Birchard Taylor and Lewis F. Moody, both of Wm. Cramp & Sons, Philadelphia. *Evening Session.* Subjects: "Public Utility Industry in the United States," by Samuel Insull, President, Commonwealth Edison Company, Chicago; "Distribution of Hydroelectric Power in Ontario from the Standpoint of the Municipal Customer," by P. B. Yates, Public Utilities Commission, St. Catharines, Ont.; "Queenston-Chippawa Power Development—General Description of Structures and Construction Problems" (illustrated), by H. G. Acres, Hydroelectric Power Commission of Ontario; "Queenston—Chippawa Power Development—Electrical Features" by Edgar T. H. Brandon, Hydroelectric Power Commission of Ontario; "Queenston-Chippawa Power Development—General Features of Design" (illustrated) by T. H. Hogg, Hydroelectric Power Commission of Ontario. Attendance 398.

Pittsburgh.—February 7, 1922, Chamber of Commerce Auditorium. Subject: "Metallic Resistor Electric Furnace, Yesterday and Today." Speaker: Mr. E. F. Collins, of the General Electric Company. Attendance 88.

March 15, 1922, Chamber of Commerce Auditorium. This meeting was designed with the purpose in view of bringing together the manufacturers of electrical equipment, the producers of electrical power and the users of both equipment and power, for a free and open discussion of their mutual problems. The following papers were presented: "Electricity In and Around a Coal Mine" by H. J. Nelms, New Fields By-Products Company; "Electrical Problems in the Department Store" by E. R. Roberts, Mechanical Superintendent of Kaufmanns; "Factors Governing Maintenance Policies for Industrial Electrical Apparatus" by A. C. Cummins, of the Duquesne Works, Carnegie Steel Company. Attendance 251.

Portland.—March 9, 1922, Y. M. C. A. Auditorium. Special Meeting. Subject: "Construction of the Caribou Power Plant and Development for the Great Western Power Company of San Francisco, Cal." Speaker: Mr. W. D. Shannon, of the Stone and Webster Engineering Corporation. Attendance 150.

March 14, 1922, Reed College Chemical Laboratory. Subject: "Some Fields Common to Chemistry and Electricity," with reference to the production of chemicals. Speaker: Professor R. K. Strong, of the department of chemistry, Reed College. Attendance 63.

Rochester.—March 24, 1922. Subject: "The Electric Furnace—The Modern Melting Machine." Speaker: Mr. H. M. St. John, vice-president and service manager of the Detroit Electric Furnace Company. The talk was illustrated with lantern slides. Attendance 44.

St. Louis.—March 22, 1922, Engineers' Club. Subject: "Recent Developments in Radio Telephony" (illustrated).

Speaker: Mr. F. H. Kroger, Engineer for the Radio Corporation of America, New York. Attendance 195.

Schenectady.—March 17, 1922, Edison Club Hall. Subject: "Electric Transmission Problems." Speaker: Mr. F. W. Peek, Jr. The lecture was illustrated by charts, lantern slides and a moving picture. Attendance 175.

April 7, 1922, Edison Club Hall. Subject: "Isotopes and Their Bearing on the Electrical Conception of Matter." Speaker: Mr. F. W. Aston, M. A., D. Sc., F. R. S., of Cavendish Laboratory, Cambridge, England. The lecture was illustrated with lantern slides. Attendance 225.

Seattle.—March 15, 1922, Engineers' Club. Subject: "The Principles and Practises of Electric Arc Welding." Speaker: Mr. A. G. Bissel. Attendance 63.

Syracuse.—February 10, 1922, Chamber of Commerce. Subject: "Static Electricity." Speaker: Vice-Chancellor William P. Graham, of Syracuse University. Attendance 50.

March 13, 1922, Onondaga Hotel. Joint meeting with the Technology Club of Syracuse. Subject: "The Superpower System." Speaker: Mr. Henry Flood, Jr. Attendance 150.

Toronto.—March 10, 1922. Open meeting and ladies' night. Subject: "Wireless and Carrier Wave Telephony." Speaker: Charles A. Culver, Ph.D. During the lecture a loud speaking set was connected in, and the speaker frequently interrupted his discourse while parts of the programs from broadcasting stations were received. At the close of the talk the time signals were received from Washington. Refreshments were served. Attendance 400.

March 24, 1922, Westinghouse Auditorium, Hamilton, Ontario. Joint meeting with Hamilton Branch, Engineering Institute of Canada. Subject: "220,000-Volt Transmission." Speaker: Mr. J. F. Peters, of the Westinghouse Electric and Manufacturing Company, Pittsburgh. The lecture was illustrated by a generous showing of charts, diagrams and lantern slides. Refreshments were served. Attendance 200.

April 7, 1922, Electrical Building, Toronto University. Subject: "Power Factor." Speaker: Mr. H. W. Price, Associate Professor of Electrical Engineering, Toronto University. Attendance 190.

Urbana.—March 16, 1922, Physics Laboratory, Urbana. Subject: "The Art of Illumination." Speaker: Mr. James M. Ketch, National Lamp Works. Attendance 85.

Utah.—March 18, 1922, Ball Room, Hotel Utah. Second general meeting and annual banquet of the Engineering Council of Utah, of which the Utah Section of the A. I. E. E. is a member. Secretary of Commerce Hoover was the guest of honor and principal speaker, and delivered an address on the work and ideals of the engineer. The members of the Colorado River Commission were also present, together with the Governor of Utah, and men interested in the Colorado River problem. Attendance 560.

March 31, 1922, Gold Room, Commercial Club. Subject: "Illumination and Eye Strain." Speaker: Mr. H. T. Plumb, President of the Engineering Council of Utah. Attendance 60.

Vancouver.—February 14, 1922, Hotel Vancouver. Joint meeting with the Canadian Institute of Mining and Metallurgy, and merged in the afternoon session of the Annual Convention of that body. Subject: "Storage Battery Locomotives for Mine and Industrial Haulage." Speaker: Mr. T. H. Crosby. Attendance 15.

March 3, 1922, Board of Trade Auditorium. Subject: "The Development of the Hydroelectric System of the British Columbia Electric Railway Company." Speaker: Mr. John I. Newell, Electrical Superintendent of the company. The talk was illustrated by slides. Attendance 39.

Washington.—March 14, 1922, Cosmos Club. *First paper:* "Street Illumination" by Mr. Henry Schroeder, of the Incandescent Lamp Sales Department Edison Lamp Works, Harrison, N. J. This paper was illustrated by lantern slides, followed by one reel of motion pictures entitled "A Trip Through the Edison Lamp Works with Thomas A. Edison." *Second paper:* "Methods of Light Utilization and Principles Underlying Illumination of Streets," demonstrated by means of models by Mr. Cromwell A. B. Halvorson, Jr., of the General Electric Company. Attendance 103.

Worcester.—March 8, 1922, E. E. Building, W. P. I. Subject: "Relation of Research to Manufactured Product." Speaker: Mr. Charles E. Skinner, of the Westinghouse Elec. & Mfg. Co., Pittsburgh, Pa. Attendance 68.

PAST BRANCH MEETINGS

Armour Institute of Technology.—March 3, 1922. Subject: "Furnaces, Gas, Fuel Oil, and Electric." Speaker: Professor N. Lesser. Attendance 54.

March 31, 1922. Subject: "Electrical Inspection." Speaker Mr. V. H. Tousely, chief Electrical Inspector for the City of Chicago. This was a joint meeting with the Branch of the A. S. M. E. Attendance 109.

Brooklyn Polytechnic Institute.—March 17, 1922. Subjects: "Wireless Transmission" by Mr. H. Wolfson (Student); and "Cable Construction" by Mr. F. Westbrook, of the Habirshaw Electric Cable Company. Refreshments were served. Attendance 30.

Bucknell University.—April 5, 1922. Subject: "Hydroelectric Development." Speaker: Professor Rhodes. Attendance 30.

University of California.—March 22, 1922. Subject: "Power Indicating Systems of the Chicago, Milwaukee & St. Paul"(particular reference to the measurement of power at a point distant from its use). Speaker: Mr. A. W. Copley, of the Westinghouse Electric & Manufacturing Company. Attendance 35.

March 29, 1922. Joint meeting of the Student Branches of the A. S. M. E., A. S. C. E. and A. I. E. E., under the auspices of the A. S. M. E. Subject: "Kern River Plant No. 3," an 800-foot head hydraulic plant of the Southern California Edison Power Company. Speaker: Mr. E. C. Hutchinson, of the Pelton Waterwheel Company, San Francisco. Attendance 124.

Carnegie Institute of Technology.—April 6, 1922. Subjects: "Feasibility of Superpower System Between Boston and Washington" by L. J. Whitehead; "Construction of a Radio Receiving Set" by Branko Lazich; "Experiences of A Commercial Wireless Operator in South America" by W. S. Andrews. Attendance 51.

Case School of Applied Science.—March 14, 1922. Subject: "Telephone Traffic." Speaker: Mr. R. E. Irwin, of the Ohio Bell Telephone Company. Attendance 25.

University of Cincinnati.—February 27, 1922. Subject: "Telephone Repeaters." Speaker: Mr. E. R. House, E. E. '22. Attendance 40.

March 6, 1922. Subject: "Geology and Engineering." Speaker: Prof. J. Fenniman. Attendance 42.

March 20, 1922. Subject: "The Uses of Electricity on Shipboard." Speaker: Mr. W. E. Thau, of the Westinghouse Electric & Manufacturing Company. Attendance 101.

Colorado Agricultural College.—March 23, 1922. Professor E. B. Dale gave an interesting demonstration of his wireless receiving set. News items, markets and weather reports, and several musical selections broadcast by the Fitzsimmons Hospital and by Dr. Reynolds, of the Reynolds Radio Company, Denver, were received. Attendance 25.

Cooper Union.—February 25, 1922. Subject: "Loud Speaking Telephone." Speaker: Mr. F. J. Ward, of the American Telephone & Telegraph Company. Attendance 50.

March 1, 1922. Subjects: "Automatic Telephony" by Mr. S. F. Peck, Jr., and "Manufacture of Carbon and Tungsten Lamps" by Mr. Russell. Attendance 20.

March 11, 1922. Subject: "Problems Arising in the Distri-

bution of Power to a Modern City." Speaker: Mr. Barnett, of the General Electric Company. Attendance 45.

March 18, 1922. Subject: "Past, Present and Future." Speaker: Professor Charles F. Scott, of Yale University. Radio Concert, prepared by Mr. Norman L. Towle, instructor; inspection of apparatus and precision instruments offered by courtesy of Kueffel & Esser Company, Sperry Gyroscope Company, Precision Instrument Company, and Chas. Sticht Company; sound wave projections, prepared by Professor Bateman. Refreshments were served. Attendance 300.

Iowa State College.—March 15, 1922. Election of officers as follows: Chairman, Clarence H. Hoper; vice-chairman, Ralph R. Gobeli; secretary, George L. Seaton; treasurer, Harold K. Johnson. Subject: "The Keokuk Hydroelectric Installation" (illustrated by about seventy-five slides). Speaker: Mr. Davis, of the Mississippi River Power Company. The paper was written by Mr. Sears, manager of the Keokuk Plant. Attendance 116.

State University of Iowa.—March 22, 1922. Subjects: "Roads Open to Technical Graduates on Completion of School" Lnd "The Hydroelectric Generator at the Iowa City Electric Aight Plant," by Messrs. Pals and Paintin, respectively. attendance 30.

University of Kentucky.—March 5, 1922. Subject: "Salesmanship." Speaker: Acting Dean W. E. Freeman. Attendance 39.

March 22, 1922. Subject: "Some Principles in Commerce and Industry." Speaker: Mr. Whiting Williams. Attendance 214.

Lafayette College.—February 16, 1922. Subjects: "Superpower Development" and "The Automatic Telephone," by Messrs. E. C. Benjamin, Jr. and R. Van Horn, respectively. Attendance 17.

February 23, 1922. Subject: "Power Transmission." Speakers: Messrs. Philip Brown and Samuel Cuniglio. Attendance 17.

March 16, 1922. Subjects: "High-Voltage D-C. Transmission, Thury System" and "Water Power Development" (illustrated), by Messrs. Kenneth Pitt and W. H. Hahn, respectively. Attendance 17.

March 23, 1922. Subjects: "Inductive Interference as Applied to the Telephone" and "The Evolution of the Electric Furnace Electrodes," by Messrs. R. P. Lowe and Paul Seigman, respectively. Attendance 17.

Lehigh University.—April 6, 1922. Subjects: "Small Power Stations" by W. H. Lutz '22; and "Equipment of Large Generating Stations" by Raymond Bailey, of the Philadelphia Electric Company. Attendance 38.

Massachusetts Institute of Technology.—March 7, 1922. Subject: "Relation of Research to Manufacture." Speaker: Mr. C. E. Skinner, of the Westinghouse Electric & Manufacturing Company. Attendance 30.

March 28, 1922. Subject: "The Relation of College Education to a Man's Life Work." Speaker: Mr. Farley Osgood, of the Public Service Electric Company, Newark, N. J. Attendance 35.

Michigan Agricultural College.—March 15, 1922. Election of officers as follows: Chairman, E. A. Pryce; secretary-treasurer, J. G. Lauffer; executive Committee, C. W. Fessenden and V. C. Pino. Subject: "Illumination and Its Effects." Speaker: Professor L. S. Foltz. Attendance 25.

University of Michigan.—March 23, 1922. "All-Electrical" Smoker. Addresses were made by the following: Professor John C. Parker, and Messrs. C. S. Coler and B. G. Lamme, both of the Westinghouse Electric & Manufacturing Company. Refreshments were served. Attendance 125.

School of Engineering of Milwaukee.—January 25, 1922. Subject: "The Use of Aluminum in the Machine Tool Industry." Speaker: Mr. J. B. Armitage, of the Kearney & Trecker Company, Milwaukee, Wis. Attendance 9.

February 26, 1922. Subject: "The Testing of Power Meters." Speaker: Mr. Jesse Miller, of the Milwaukee Electric Railway & Light Company. Attendance 24.

University of North Carolina.—April 6, 1922. Subjects: "Nothing in Particular," by T. B. Jacocks, Jr.; and "The Electric System on Motor Cars," by G. T. Finger; "The Superpower Zone," by W. K. Harding. Attendance 24.

University of Notre Dame.—March 13, 1922. Reports were presented of the trip to the Elkhart Power Plant. Mr. Michaelson, Chief Engineer of the South Bend and Northern Indiana Railway Company, was present and delivered a short talk. Lunch was served. Attendance 21.

Ohio Northern University.—March 16, 1922. Subject: "Electrical Safety Appliances." Speaker: Mr. J. C. Barnes. Attendance 25.

March 30, 1922. The principal feature of the meeting was the discussion of the hyperbolic function, by Professor Beckwith. He explained the functions in their various forms and their value to electrical engineers. Attendance 36.

Ohio State University.—March 29, 1922. Subjects: "Outside Construction Problems" by Mr. Paul J. Howe, and "Multiplex Systems" by Mr. Cogswell, both of the Western Union Telegraph Company. Attendance 47.

Oklahoma A. & M. College.—March 6, 1922. Subjects: "Muscle Shoals" by W. H. Long; and "The Use of Electricity in the Oil Fields" by Lawrence Benner. Attendance 30.

University of Oklahoma.—March 30, 1922. Subjects: "Electricity in the Automobile Industry" by J. A. Diffendaffer; "Electric Furnaces and Their Characteristics as Used in the Steel Industry" by S. R. Roush; "Hydroelectric Power Development" by R. Cooper; "Electrical Engineers and The Survival of the Fittest" by W. A. Seifert. Attendance 23.

Oregon State College.—March 9, 1922. Discussion of plans for the coming Engineering Show. Attendance 16.

University of Pittsburgh.—March 23, 1922. Subject: "European Electrification" (illustrated). Speaker: Mr. F. E. Wynne, of the Westinghouse Electric & Manufacturing Company. Attendance 95.

March 30, 1922. Subjects: "Protective Devices" by Mr. Ward; "Electric Blast Furnaces" by Mr. Nesbit; and "Westinghouse Method of Testing Distributing Transformers" by Mr. Langguth. Attendance 40.

Rutgers College.—March 9, 1922. Subject: "The Superpower System." Speaker: Mr. E. F. O'Dair '22. Attendance 7.

March 23, 1922. Subjects: "Sound Range Finding" by E. S. Cawthorne '23; "Lightning Phenomena and Lightning Protection" by E. J. Butler '23. Attendance 14.

University of Southern California.—March 8, 1922. Demonstration and lecture by Messrs. Barkley and Menenhall, of the United States Electrical Manufacturing Company, of Los Angeles, on the motors manufactured by them. Attendance 19.

March 22, 1922. A talk and demonstration on the wireless telephone and telegraph was given by Mr. E. T. House. Attendance 15.

Syracuse University.—March 3, 1922. Subject: "The New York Central Signal System." Speaker: Mr. Minor P. Avery. Attendance 7.

March 10, 1922. Subject: "Hydroelectric Power and Its Use in Industry." Speaker: Mr. Ralph H. Baker. Attendance 7.

March 17, 1922. Subject: "Electric Elevators." Speaker: Mr. A. P. Fugill. Attendance 4.

Washington State College.—March 24, 1922. Subject: "The Superpower Zone." Speaker: Mr. Arthur E. Bond. Attendance 15.

University of Washington.—April 4, 1922. Subject: "Telephone Transmission." Speaker: Mr. W. D. Scott. Attendance 31.

West Virginia University.—March 20, 1922. Subjects: "Heavy Duty Electrical Heating Apparatus" by G. S. Nease;

"Reducing Manufacturing Costs by Central Stations" by R. K. Park; "Electric Power Application to Passenger and Freight Elevators" by C. C. Cantner; "Automatic Railway Substation Economy" by L. T. Faulkner; "Radio Broadcasting" by Guy A. Moffett; "Electrico-Porcelain" by I. O. Meyers; "Effect of Moisture on Thermal Conductivity of Soils" by A. C. Price; "Structure of the Atom" by C. B. Hutson. Attendance 26.

April 10, 1922. Subjects: "Electric Traction by A. E. La Poe, and "Switchboards" by C. M. Hill. Attendance 27.

University of Wisconsin.—March 8, 1922. Joint meeting of the A. I. E. E. Branch and Madison Section. Subject: "Electric Welding" (illustrated). Speaker: Mr. Candee, of the Westinghouse Electric & Manufacturing Company. Attendance 22.

March 15, 1922. Election of officers as follows: Chairman, R. H. Herrick (reelected); secretary-treasurer, J. W. Smart; executive committee, Professor Bennett and Messrs. Guillemin, Bjornson and Rusch. Attendance 23.

March 29, 1922. A general discussion was held on the subject of "The Prospects of a College Graduate in the Engineering World." Attendance 18.

Yale University.—February 24, 1922. Reception given to Yale Freshmen by the Student Branches of the A. I. E. E., A. S. M. E., A. S. C. E. and A. I. M. E. Motion pictures were shown of the Caribou Hydroelectric Development in California and demonstration made of various pieces of apparatus in the laboratories of mechanical and electrical engineering. Refreshments were served. Attendance 300.

March 21, 1922. Two motion pictures were shown: "The Revelations of the X-Ray" and "The King of the Rails." Attendance 175.

March 28, 1922. Subject: "The Human Voice and Its Transmission." Speaker: Mr. John Mills, of the Western Electric Company. Attendance 250.

Employment Service Bulletin

OPPORTUNITIES.—Desirable opportunities for service from responsible sources are announced in this Bulletin, and no charge therefor is made.

MEN AVAILABLE.—Under this heading brief announcements (not more than fifty words) will be published without charge to the members. Announcements will not be repeated except upon request received after a period of three months, during which period names and records will remain in the active files.

NOTE.—Notices for the JOURNAL ***should be addressed to EMPLOYMENT SERVICE, 33 West 39th Street, New York, N. Y.,*** *the employment clearing house of the Societies constituting the Federated American Engineering Societies, and* ***not*** *to the A. I. E. E.*

Notices for the JOURNAL are not acknowledged by personal letter, but if received prior to the 16th of the month will appear in the issue of the following month.

All replies to either "Opportunities" or "Services Available" should be addressed to the key number indicated in each case ***and forwarded to EMPLOYMENT SERVICE, as above.***

Replies received by the bureau after the position to which they refer has been filled will not be forwarded, and will be held by the bureau for one month only.

Information regarding the notices published is on file in the offices of the member societies of the Federated American Engineering Societies.

POSITIONS OPEN

LARGE MANUFACTURER OF MAGNET CONTROLLERS has opening for engineer who is familiar with design and application of a-c. and d-c. magnet controllers. Position requires man who has had considerable experience in this line of work and who is capable of taking charge of the development of a line of contractors and controllers for special application. Liberal salary. Location, New York City. V-444.

DESIGNERS of electrical switching apparatus, oil circuit breakers, carbon circuit breakers and outdoor switching devices. Graduate of good technical school preferred. Application by letter stating age, experience and salary expected. Location, Pittsburgh, Pa. V-514.

RESIDENT ENGINEER. Must be man of considerable experience in medium head hydroelectric developments, especially on dam design and construction, and hydraulic end of work. Electrical part is not of such great importance. Application by letter. Salary not stated. Location, Poughkeepsie, N. Y. V-791.

RESEARCH ENGINEER. Attractive position with exceptional opportunities open to man having right qualifications. Requires ability to apply sound scientific principles and reasoning to analysis and solution of wide variety of general technical problems demanding fundamental research. Problems mainly in general field of mechanical engineering, although many typical of physics and chemistry, some requiring special mathematical ability. Applicants should have not less than 5 years active experience in research along lines indicated above. Should have advanced scientific as well as engineering training, with special regard to fundamentals rather than to details of engineering practise. Courses of instruction, for instance, as lead to advance degrees in physics, chemistry and mathematics, with special reference to mechanics and thermodynamics, are of much importance. Equally important is sound knowledge of practical engineering problems and appreciation of various factors which must be considered in applying scientific analysis to these problems. Applicant should state particularly lines of engineering with which he is familiar and extent of acquaintance with other engineers in these lines. Ability to summarize scientific and technical papers and to write up technical material for publication is of importance, as is ability to maintain cordial relations with other engineers engaged in similar lines of work. Application by letter. State when available and salary. Location, N. Y. City. V-629.

INSTRUCTORS (2), for term beginning next September for department of physics. Work will consist in total of not more than fourteen hours weekly with recitation and laboratory sections in elementary physics. Possession of a doctor's degree by candidates is not absolutely essential but it is desired to find men who are interested in physics and who may be counted upon to go forward in their studies. Every encouragement in the way of arrangement of schedule of hours and in securing facilities for research will be given. Application by letter. Location, New York City. V-637.

ENGINEER, high grade, familiar in manufacture of wireless sets, man knowing costs, etc. Right man can create his own opportunity. Application by letter. Salary not stated Location, New York City. V-672.

RADIO RESEARCH ENGINEERS & PHYSICISTS. University or commercial radio research experience. Must be able to plan and carry out independent experimental investigations in fields of short and long-distance wave transmission, radio telephone receivers and transmitters, and kindred subjects. Write, including references to publications, experience, salary desired and time of availability. Application by letter. Salary not stated. Location, New York City. V-691.

BROAD GAGE ELECTRICAL ENGINEER, thoroughly experienced on power plant, hydroelectric and public utility layout. Must be good mixer as well as engineer. Unusual opportunity. Good future. Application by letter. Location, New York City. V-695.

ENGINEER to act as load dispatcher or assistant operator of electric railroad. Must be familiar with high-tension transmission line work, hydroelectric and steam plants. Position will be open in from one-two months. Application by letter. Location, Maryland. V-697.

ELECTRICAL DRAFTSMAN substation and power house layout. Application in person. Location, New York City. V-700.

ENGINEER about 27-30 years of age, preferably with chemical training, whom we could develop as salesman for cyanide products. Knowledge of either electroplating industry or case hardening and heat treating of steel would be good ground work for this position. Young man who has had some schooling in use or sale of chemicals in electroplating industry would prob-

ably fill requirements. Applicant who has knowledge of case hardening and heat treating of steel would also be favorably considered. Application by letter. Salary not stated. Location, N. Y. City. V-711.

SWITCHBOARD OPERATORS (2), experienced on high voltage work. Eight hour shifts. Expenses paid both ways. Two years contract. Application in person. Location, South America. V-750.

SALES MANAGER. Partnership desired with manufacturer to build up business. Willing to invest capital and take entire charge of marketing product. V-762.

ELECTRICAL ENGINEERING GRADUATE, with experience in testing, to plant and supervise test work and analyze results thereof. Good opportunity for ambitious young man. Application by letter. Location, Yonkers, N. Y. V-825.

EXPERIENCED SALESMEN to handle the sale of a line of quality dial gages. Should have experience and acquaintance among users of this product. Application by letter. Salary not stated. Headquarters, New York City. V-837.

ELECTRICAL ENGINEER to act as divisional engineer who would be in charge of electrical maintenance and new construction in his district, of generating stations, substations and transmission lines. We have approximately 100,000-kw. capacity of steam and hydro plants. System is divided up into three districts, and engineer would have charge of one district. Application by letter. Location, N. Y. State. V-851.

ELECTRICAL ENGINEER who has had actual practical experience in the construction of electric cooking and heating apparatus from both designing standpoint as well as manufacturing standpoint. Application by letter. State salary expected and give full details with reference to experience. Location, Ohio. V-855.

ELECTRICAL ENGINEER. With experience on transformer design. Splendid opportunity. Application by letter stating age, education and practical experience. Location, Pa. V-867

ELECTRICAL DRAFTSMAN. Must be experienced on power house and substation work. Will not consider anyone who has not had this experience. Application in person. Salary not stated. Location, Brooklyn, N. Y. V-873.

ELECTRICAL ENGINEER, who has an acquaintanceship among wholesalers of wireless telephone equipment. Need man who has such connections to be on the ground in New York and buy whatever equipment we need which he may be able to pick up. Such would probably mean calling on wholesalers every day so that he might be on hand in case equipment came in. It probably would not require but part of man's time. Expect to pay straight commission on buying and if such man has a good acquaintanceship among the wholesalers he should be able to make from $50-75 a week in commissions. Do not expect he will have to put up any money himself. Would consider man who might even be looking for a position along other lines but who would like to fill in while locating the other job by doing our New York buying. Headquarters, Boston, Mass. Application by letter. V-884.

SANITARY & HEATING ENGINEER for taking off quantities from plans. (Large and small buildings, schools, etc.). Application by letter. Location, Washington, D. C. V-891.

PIPE CONVEYING ESTIMATOR. Must have actual experience on the various types of heating and ventilating system. Application by letter. Salary not stated. Location, New York City. V-904.

ESTIMATORS. Trained salesman to follow up architects and builders in and about New York City, and obtain contracts for electrical construction, also follow up industrial establishments for orders for yearly maintenance and repair of electrical machinery and elevators. Opportunity for able man to become essential part of established concern. Commissions, drawing account and bonus. Application by letter. Headquarters, New York City. V-913.

MECHANICAL OR ELECTRICAL ENGINEER with some operating experience. Should have a thorough knowledge of physics, especially thermo-dynamics. Experience in the operation and design of temperature and pressure instruments and flow meters is essential. Work in instruments control dept. covers design and control of a large variety of instruments used in manufacture of automobile tires. Most of work is laboratory work. Application by letter. Salary not stated. Location, Ohio. V-924.

APPRENTICE for lamp factory. Recent graduate. Application in person. Salary $25 week. Location, New Jersey. V-930.

ENGINEER with experience in designing switchboards and men who have experience in diagram work in connection with the layout of power houses and substations. Application by letter. Salary not stated. Location, Pa. V-954.

ELECTRICAL REPAIR MAN & TROUBLE SHOOTER. Should be graduate E. E. Must know Spanish. Single man preferred. Position will lead to foreman of repair shop. Application by letter. Salary not stated. Location, Chile. V-982.

FOREMAN of instrument laboratory. Position requires man with thorough knowledge of electrical indicating instruments both portable and station type, such as wattmeters, voltmeters, ammeters, etc. Prefer technical graduate or man who has had previous practical experience along these lines, which would be equivalent to technical education. Application by letter. Salary not stated. Location, New Jersey. V-993.

ENGINEER with ten to fifteen years experience in elevator business; a man with sufficient presence and ability to meet leading engineers in building industry and assist them in calculating size, number, speed and load of elevators for any particular building. Application by letter. Salary not stated. Location, Pa. V-994.

ENGINEERS, electrical, mechanical, railroad, interested in the electrification of Siberian industries and railways. Application by letter giving age, experience, and reference. Salary not stated. Headquarters California. Location Siberia. V-997.

ASSISTANT TO MANAGER. Manager of interurban property desires an assistant, at present in capacity of statistician or chief clerk. Young man who has had railway engineering and operating experience. Must have been out of college at least five years in pursuit of this line of work. Wood pole transmission line experience desirable. Application by letter supplying photograph and statement of family, statement of professional record with references in letter of application. Location, Western New York State. Advancement to position of executive responsibility entirely dependent upon applicant. V-996.

INSTRUCTORS: All engineers willing to consider teaching positions are invited to register with the Employment Service, which has been called on to fill positions varying in grade from laboratory assistant to heads of departments in various engineering and technical schools of this country. Blanks for registration and information regarding the Bureau may be had by addressing Mr. Walter V. Brown, Manager Employment Service, 29 West 39th St., New York City.

MEN AVAILABLE

TECHNICAL GRADUATE IN ELECTRICAL ENGINEERING—age 23, with very little practical experience, but wants to secure a good position to obtain some. Will consider anything, but outside work preferred. E-3285.

ELECTRICAL ENGINEER—age 34, for past eight years with one of the largest mining companies operating in South America will be available August 1st, 1922. E-3286.

ELECTRICAL ENGINEERING GRADUATE—single—five years experience in large modern office building power plants—last 4½ years as technical assistant to chief engineer, wishes position with public utility company, electrical manufacturing or construction concern, where advancement is possible. E-3287.

TECHNICAL GRADUATE IN ELECTRICAL ENGINEERING, age 25, desires position in or about New York City with an electrical or automotive company which offers opportunity for advancement—have had very little practical experience but am a ready and willing learner. Position last held was of executive nature, with an electrical machinery export house. Available July 1st. E-3288.

YOUNG ELECTRICAL ENGINEERING GRADUATE, having had eighteen months experience on General Electric Co. test, an Associate of A. I. E. E. desires a position in electrical engineering work in which there is opportunity for advancement. E-3289.

ELECTRICAL ENGINEER, age 26; married; associate A. I. E. E.; ex-service man; 2 years college; diploma I. C. S. electrical engineering course; experience; design of electric controlling devices, especially elevator control; also varied drafting experience. Desires position with manufacturing concern in middle west. Present salary $1800. E-3290.

GRADUATE ENGINEER, B. Sc. in Electrical Engineering, W. P. I. 1915, Member A. I. E. E. Age 29. Single. In charge of car equipment test department of one of the largest subway, elevated and surface car companies for past six years with exception of one year in Navy, (ensign) assigned to experimental work on anti-submarine devices. Plenty of initiative, push and executive ability. Minimum salary $3300 but a real chance of advancement is most important. E-3291.

YOUNG MAN, technical graduate, age 32, wishes to invest about $2000 with services either in retail electrical business, public utility in city of four or five thousand people or electrical repair shop. Have had wide experience in power plant operation, some construction experience and at present employed. E-3292.

STEAM-ELECTRIC PLANT ENGINEER—Technical Graduate, seven years with General Electric Company in test, laboratory, design, developmental and commercial engineering. Three years steam plant testing and engineering. Familiar with engine and boiler room practise and various metering devices of the modern steam turbine plant. E-3293.

ELECTRICAL ENGINEER OR ASST. ELEC. SUPT. for Industrial Plant (Steel Mill preferred), familiar with switching equipment and requirements for industrial application. Technical graduate, year 1916, with experience in design of substations and power plants for industrial concerns. Familiar with latest types of manual and automatic switching equipment. E-3294.

ELECTRICAL ENGINEER technical graduate, 38, married, just returned after spending 14 months in Europe organizing and supervising agencies. Fifteen years experience in industrial and power plant sales engineering with layout British, German, Dutch and American electrical concerns in different parts of the world. Desires permanent position in engineering sales or executive work, export or domestic, preferably in East. Speaks fluently Dutch and German. E-3295.

EXECUTIVE AND ENGINEER—Desires executive position. Fourteen years practical experience with prominent concerns leading from nveralls to superintendent. Thoroughly trained io the manufacture of general machinery and electrical apparatus. Expert in the design and building of labor saving machinery; systematizing; planning; inspection; speedy, cheap and accurate production; safety work; handling apprentices and drafting room practise. Graduate of a real engineering school. Age 36. Married. E-3296.

TECHNICAL STUDENT, Student Member A. I. E. E.; age 27; taking night course in electrical engineering, desires position with electrical engineering concern offering advancement and future. Location at present Minnesota; prefer middle west. Would continue school in new location. Three years electrical experience. Salary open. E-3297.

ELECTRICAL ENGINEER—Will graduate from a leading eastern university in June. E. E. degree. Desires position with some medium sized electrical manufacturing company. Specialized in electrical machine design. Now instructing. Age 25. Married. E-3298.

ELECTRICAL ENGINEER—technical graduate; Assoc. A. I. E. E. age 28. Six years experience in testing laboratory radio, chief engineer of marine installation and maintenance; remote control, machine tool application, estimating and construction work. Desires permanent position with well established company, planning estimating and following up progress of jobs. Location preferred Newark or New York City; available one month. E-3299.

MECHANICAL AND POWER ENGINEER—technical graduate, eight years experience, machine shop, metallurgy, sugar engineering, industrial and power plant practise, operation, design, layout, calculations, heat-balance, utilization and distribution of steam, water, coal, power, etc., investigation, research, reports. Executive and business ability. E-3300.

GRADUATE ELECTRICAL ENGINEER; age 29. Experience includes two years of G. E. test and over three years of general engineering work consisting of investigations and reports on power and transmission problems, use of calculating table for network studies, power rates, etc. Desires position with a hydroelectric company or with a firm of consulting engineers. Salary $2500. E-3301.

ELECTRICAL ENGINEER—age 30, married, Assoc. A. I. E. E. technical education. Three years Westinghouse electric service dept., 7 years as engineer and chief electrician with two large iron mines in New Jersey. Varied experience with practically all kinds of electrical installations tests and repairs. Excellent references, available short notice. Work of permanent nature desired. E-3302.

ELECTRICAL ENGINEER available for domestic or foreign service. Sixteen years experience American, European and Far Eastern markets. Fluent French and German. Member A. I. E. E. and A. S. M. E. E-3303.

ELECTRICAL ENGINEER, technical graduate, open for position. Fifteen years' experience in electrical railway and power plant work. Can take charge of operation or construction work. Familiar with all the operating, maintenance and construction work in the above fields, including high-tension lines. Experienced in laying out work and estimating costs. E-3304.

CIVIL AND GRADUATE ELECTRICAL ENGINEER M. I. T. 1916, married, age 29, now Lieut. (jg) Civil Engineer Corps, U. S. N., located in New Jersey invites correspondence with reliable engineering concern for position in sales or publicity department. Satisfactory references covering college and other work will be furnished. One year in France with Signal Corps, U. S. Army. E-3305.

ENGINEER—Two University Degrees; age 37; single; taught electricity and electrical engineering; desires assistant or associate professorship of electricity and electrical engineering. E-3306.

TECHNICALLY EDUCATED MAN—thirty-three, wishes employment in electrical, or electrical and mechanical work combined. Has had eight years experience with General Electric Company, two years construction, two years electrical inspection work, and three years as master mechanic of oil refinery. E-3307.

ELECTRICAL ENGINEERING STUDENT, third year, desires an opportunity with an engineering, manufacturing or contracting concern for the summer months with the expectation of making a permanent connection upon graduation in June 1923. Two years general business experience. Available end of June. E-3308.

SALES ENGINEER—ELECTRICAL ENGINEER with four years practical experience along power apparatus lines including over one year as a sales engineer for prominent manufacturer of alternating-current motors, at present employed, desires change to position assuring a future where ability, ambition and horse sense will bring their rewards. Location immaterial. E-3309.

ELECTRICAL ENGINEER—technical graduate, age 40, married, desires position with public utility, manufacturer, contractor, or consulting engineer. Is thoroughly familiar with Westinghouse apparatus, being able to design and apply all types of switching equipment, relays, and protective apparatus, either for low or high tension. E-3310.

JUNE GRADUATE IN ELECTRICAL ENGINEERING, with adequate ambition, determination and patience, with relatively advanced qualifications in clerical, commercial and sales work, with good character, and a knack of working hard—desires employment (whether starting with hammer or pen) where exceptional service will lead to a good future. Age 23; free after graduation. E-3311.

ASSISTANT CHIEF ENGINEER AND SUPERINTENDENT. Graduate electrical engineer, 36 years old with 17 years experience supervising designs, construction and operation of power and substations, industrial plants, transmission systems and handling reports on investigations for electrolysis, desires position where high class executive ability is required. E-3312.

EXECUTIVE ELECTRICAL ENGINEER, with 15 years of consulting practise, desires position with public utility, manufacturer, or banking house. A careful analyzer, very thorough and a man who can produce results. Present salary $8500. E-3313.

EUROPE—Progressive and wide awake American will sail for Europe June 1st. While abroad will attend to any practical proposition or personal matter upon very reasonable terms. Radio propositions especially acceptable. Will be in New York last week in May for interview. Associate A. I. E. E. E-3314.

ELECTRICAL ENGINEER; desires teaching position in radio engineering in some standard university, where development and research might be carried on. Graduate with good scholastic standing from one of the best engineering schools. Well laid foundation in mathematics, physics, and engineering, including radio. Practical and teaching experience. Best references. Associate A. I. E. E. and I. R. E. E-3315.

ENGINEER EXECUTIVE—Mechanical and Electrical. Fifteen years experience in the manufacture of electrical apparatus and internal combustion engines, from design to test. Good knowledge of manufacturing accounts. Extended experience with small electric lighting sets. Position desired in either production or directive engineering that will lead to factory supervision. E-3316.

YOUNG ELECTRICAL ENGINEER desires connection with a successful electrical or mechanical supply company. Have $5000 to invest in same. No "wild cat" schemes will be considered. Prefer South, or West Coast. Student A. I. E. E. E-3317.

DISTRIBUTION ENGINEER, technical graduate 1917, age 29. One year shop installation and organization. Three years design and estimating overhead and underground systems involving numerous types of transformer and substation installations of voltages up to 60,000 volts. Chief electrical engineer for a corporation the last two years. Thoroughly familiar with construction accounting. Will go anywhere for a broader field where there is a chance for advancement. Salary to depend upon opportunities offered. Doubled salary with present employer in two years. E-3318.

GRADUATE ELECTRICAL ENGINEER—Age 25. Desires position where advancement can be made. Have been an instructor in college. Have also had experience in electrical construction and telephone engineering. E-3319.

YOUNG MAN—Age 23, married, will receive degree of B. S. in E. E. June 14. Enrolled student, A. I. E. E. Assistant instructor in mechanical drawing 1921-22. Practical experience on interior wiring and distributing systems. Desires position in electrical engineering; transmission or construction work; or general plant engineering. At home in an atmosphere of work. Reasonable offer considered. Available about June 20. E-3320.

PURCHASING EXECUTIVE—trained engineer, experienced in modern production methods, shop management, cost records and stock control, purchasing and sales, desires to explain to management of manufacturing concerns how their purchasing can be organized not only to be self sustaining but also show profits through substantial reduction of inventory. If interested address. E-3321.

FACTORY EXECUTIVE—Age 35. Electrical and mechanical engineer. Fifteen years experience in the operation of industrial power plants and in factory management. Last 5 years, production manager, in large factories manufacturing electrical machinery and automobile engines. Available Oct. 1. Location immaterial. Opportunity not salary is prime consideration. E-3322.

MECHANICAL AND ELECTRICAL ENGINEER—with 12 years experience in the design, construction operation, and valuation of electric light and power plants, street railways, water works and artificial gas plants. Desires a connection as superintendent of one of the above named utilities or a combination of them—location Middle West or South. Available on 15 days notice. E-3323.

ELECTRICAL ENGINEER—age 28, married, A. I. E. E. and I. E. S. with eight years general engineering experience including year G. E. test desires position with large electrical jobber or retailer where a thorough knowledge of the incandescent lamp business would be of value. Location anywhere—preferably the East. E-3324.

ELECTRICAL ENGINEER—Five years experience on heavy power work (drafting room and field). Two years of small equipment design. Graduate of engineering college, and I. C. S. At present Alexander Hamilton business course. Desires connection demanding engineering and commercial ability offering opportunity of expansion. Prefer Central States. At present in Chicago. E-3325.

UNIVERSITY GRADUATE—Assoc. A. I. E. E. Age 32, Japanese, married, 6 years of drafting-designing experience, have sufficient knowledge and experience in mechanical structure and concrete to produce an efficient electric design. Position with consulting engineer or an industrial concern desired. Will go to Japan for an American or Japanese concern as a technical or sales representative. E-3326.

TECHNICAL GRADUATE IN ELECTRICAL ENGINEERING desires position in radio manufacturing or experimental work. Age 23. Two years experience in installation, testing and operation of radio apparatus U. S. Navy. Three

months instrument work Western Elec. Co. Available June 1, 1922. E-3327.

ELECTRICAL ENGINEER (grad). Desires position on design or construction of electric railways, transmission substations and power houses. Can also supervise the complete design and construction of industrial plants of any nature from preliminary investigations to finished product. E-3328.

ELECTRICAL ENGINEER desires position along line of illumination engineering. College graduate, 1921. Age 22. Single. Now employed. Location immaterial. E-3329.

ELECTRICAL SALES ENGINEER—29 years of age, technical education, at present located in Texas wishes connection with progressive concern as representative in Southwestern territory. E-3330.

TECHNICAL GRADUATE, married, age 34. Fourteen years experience in testing laboratories and manufacture. Familiar with oscillograph, instrument and relay testing, short-circuit calculations, generator and transformer testing and wireless. Willing to change, similar position or to wireless manufacturer. No traveling considered. Now employed. Location near New York City. Salary least $3000. E-3331.

ELECTRICAL ENGINEER—Technical graduate, age 27, Assoc. A. I. E. E. One year with industrial plant in operation of power plant and factory apparatus, one year in power plant and substation construction, 18 months test floor experience with large corporation as relay and meter specialist, desires change for broader field of activities. Available on reasonable notice. E-3332.

ELECTRICAL ENGINEER OR EXECUTIVE ASSISTANT—Technical graduate, Assoc. A. I. E. E., age 26, single. Three years teaching electrical engineering subjects and three years installation, research and testing. Experience includes switchboard and power installation and testing, design, and supervision of construction and maintenance of distribution systems. Knowledge of protective relays and control apparatus, including remote control systems. Available about August 1st. E-3333.

MECHANICAL-ELECTRICAL ENGINEER desires position as works engineer, master mechanic, electrical engineer or chief electrician. Fourteen years experience power plants, transmission lines, mechanical and electrical equipment, industrial plants. Age 31. Married. Assoc. A. I. E. E. Member A. A. E. E-3334.

ELECTRICAL ENGINEER—Age 28, single, will graduate from a recognized engineering school in the course of electrical engineering next June. Enrolled student A. I. E. E. Desires position in sales work immediately upon graduation, with growing concern. Considerable experience in sales work and with electrical equipment. Leader of men. Best of references. E-3335.

MECHANICAL ENGINEER AND TEACHER, B. S. and M. E., seventeen years' experience, fourteen as head of mechanical and electrical engineering division in a university, consulting engineering and construction work, desires change, technical, commercial or educational. E-3336.

TECHNICAL GRADUATE—Employed by U. S. Government radio department. Five years in the design, installation, calibration and maintenance of ship and shore radio compass stations. Desires position with private concern or shipping company where services would be required for this work. Age 29 years. E-3337.

GRADUATE ELECTRICAL ENGINEER with ten years experience in the operation of hydro plants, railway and distributing stations, desires a position with a power company. Available at short notice. E-3338.

ELECTRICAL AND MECHANICAL ENGINEER, 5½ years experience, graduate, age 30, married. Experience has been chiefly in test work along the following lines as applied to electrical machinery and steam turbines, commercial, experimental and research, and acceptance, test. Desires to connect with a concern having an opening for a test engineer. At present employed. E-3339.

ELECTRICAL ENGINEER—Age 29. G. E. test; capable of calculating, installing and operating electrical installations, coal mine and municipal lighting plant experience, can handle men; technical writer. References. E-3340.

ENGINEER—Age 32. Fourteen years experience as telephone and power engineer, successful experience teaching, has good knowledge of accountancy and modern business, desires connection with financial or efficiency engineering firm, will consider any good executive position; available on reasonable notice. E-3341.

PURCHASE ENGINEER—Sixteen years experience in using and inspecting electrical material; two and a half years experience in handling forest products and the past three years largely devoted to buying textiles, equipment and food stuffs for a large industrial restaurant. Now employed. Integrity and ability unquestioned. Cornell graduate. E-3342.

ELECTRICAL ENGINEER—technical graduate—age 30, 18 months G. E. test, 15 months U. S. Air Service engineering dept., 3 years designing electrical apparatus and supervisor of test, fairly educated in French, will consider a suitable position anywhere, not afraid of hard work, available on reasonable notice. E-3343.

ELECTRICAL ENGINEER, 14 years experience, experimental, development and general testing work, desires to make connection with manufacturer of radio equipment. E-3344.

SALES MANAGER, graduate electrical and mechanical engineer, University of California, fourteen years experience, desires connection sales executive property or company requiring commercial expansion and rejuvenation and where permanent future and advancement will depend upon new revenues produced. At present employed. Communications with high types of organizations solicited. E-3345.

HEAD OF DEPARTMENT, PROFESSORSHIP, ELECTRICAL ENGINEERING desired; $4000. Three years practical experience, power company, signal service, assistant to consulting engineer; two years responsible teaching; B. Sc. in E. E. 1917; qualified to teach advanced theory, laboratory, transmission, railways. Position at salary mentioned must afford time for outside practise. E-3346.

YOUNG ENGINEER—Age 24, Assoc. A. I. E. E. Technical education partly self-acquired. Seven years in the electrical field, including laboratory, construction and installation work. Familiar with transformer construction, application and designing of distribution types, also automatic and remote control substation construction. References if desired. Location New York City. E-3347.

GRADUATE ELECTRICAL ENGINEER, G. E. test, age 33, married. Have been chief safety engineer in workmen's compensation field; excellent experience in safety code work. Now doing technical and publicity work in general insurance; present salary, $4,500. Would accept responsibility for safety, insurance or analytical work in industrial plant or utility. E-3348.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED APRIL 11, 1922

ADAMS, ROBERT L., Electrician, United Railways & Electric Company, Carroll Park Shops; res., 1648 N. Bentelon St., Baltimore, Md.

*ANDERSON, ALBERT S., Sales Agent, General Electric Company, 508 U. S. National Bank Bldg., Denver, Colo.

ANDERSON, JOSEPH W., Student Engineer, Northwestern Bell Telephone Company, 122 S. 6th St., Minneapolis, Minn.

ANDERSON RAYMOND WEBSTER, Dynamo Operator, New York Edison Company, 171 W. 107th St.; res., 500 W. 141st St., New York, N. Y.

ANDRES, CHARLES PHILLIP, Chief Electrician's Mate U. S. Navy; U. S. N. Radio School, Great Lakes, Ill.

BADE, COURTLAND WALTER, Engineer, Sales Dept.,Northern States Power Company, 15 S. 5th St., Minneapolis, Minn.

AYO, ESSIE RAPHAEL, American Tel. & Tel. Company, Charlotte, N. C.

*BAGG, RAYMOND JAMES, Plant Engineer, New York Telephone Company, 81 Willoughby St.; 147 St. James Place, Brooklyn, N. Y.

BARTLETT, WALLACE ANDREW, Assistant to Field Engineer, Westinghouse Elec. & Mfg. Company, 467-10th Ave., New York, N. Y.

BARTON, HENRY A., Telephone Engineer, American Tel. & Tel. Company, 195 Broadway, New York, N. Y.

BARUCH, MILTON S., Advertising Manager, Shapiro & Aronson, Inc., 20 Warren St., New York, N. Y.

BERRY, JOEL HALBERT, Production Engineer, Virginia Railway & Power Company; res., 730 Boissevain Ave., Norfolk, Va.

BLAKE, BUEL BEECHER, Salesman, Westinghouse Electric & Mfg. Company, 1400 Alaska Bldg., Seattle, Wash.

BLINSTON, CHESTER A., Electrical Designer, F. R. Weller, 201 Mills Bldg., Washington, D. C.

BOGART, GEORGE HAROLD, Electrical Engineer, Building Dept., Western Electric Company, New York; res., 38 Homer Lee Ave., Jamaica, N. Y.

BORELLI, AURELIO, Paulista Railroad; Rua Dr. Moraes Salles 303 Campinas, Estado de S. Paulo, Brazil, S. A.

*BRACE, GEORGE ARNOLD, Sales Engineer, Canadian General Electric Company, Ltd.; res., 53 Triller Ave., Toronto, Ont.

BRAKE, REGINALD LAWRENCE, Draftsman, Canadian Westinghouse Company, Ltd.; res., 224 Sherman Ave., S. Hamilton, Ont.

BRITTINGHAM, HENRY LAWRENCE, Sales Engineer, Western Electric Company, 425 E. Oliver St., Baltimore, Md.

BROWN, WILLIAM J., Station Wireman, Union Electric Light & Power Company, St. Louis; res., Woodson Road & Bristol Ave., Overland, Mo.

BUEHLER, FRED W., Proprietor & Manager, Ottawa Electric Company, 308 W. Main St., Ottawa, Ill.

BULLIONS, CORNELIUS SHILAND, Instructor, Electrical Engineering, University of Illinois, Urbana, Ill.

*BUNTING, STEPHEN CLARENCE, Appraisal Dept., Adirondack Power & Light Corp. 26 Nott Terrace, Schenectady, N. Y.

BURGESS, G. HAROLD, Office Manager & Radio Sales Manager, Burgess Electric Company, Duluth, Minn.

CAMPBELL, ARCHIBALD STEWART, Electrical Tester, City Council Power Station, Newcastle; res., "Hillcrest", Janet St., Mereweather, Newcastle, N. S. W. Australia.

CARPER, CHESTER O., Electrician, Commonwealth Edison Company, Calumet Station, Chicago, Ill.

CARR, JOHN OLIVER, Manager, Sales Engineering Dept., Morkrum Company, 1410 Wrightwood Ave., Chicago, Ill.

CHATAJRI, NABHOMOHAN, Electrician, Tata Iron & Co., Ltd.; "34'A" Northern Town, Jamshepure, Via:—Tatanagar, India.

CHESTON, ALBERT DANIEL, In charge, Electric Dumbwaiter Dept., Elevator Supplies Company, Willow Ave. & 15th Sts., Hoboken, N. J.

CIPPERLEY, IAN, Telephone & Signal Maintainer, Pennsylvania Railroad, 227 E. Market St., Akron, Ohio.

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COGSWELL, BURNHAM, Student Engineer, General Electric Company; 16 Washington Ave., Schenectady, N. Y.

COOLEY, ELIHU H., Engineer, Western Electric Company, 463 West St., New York, N. Y.

COX, GROVER A., Supervisor Lines West, N.Y., N. H. & H. R. R. Co.; res., 387 Sherman Ave., New Haven, Conn.

CROSBY, HALSEY EMERY, Electrical Engineer, Building Dept., Western Electric Company, 463 West St.; res., 530 W. 143rd St., New York, N. Y.

CURTIS, GEORGE S., Assistant Division Superintendent, Public Service Electric Company of New Jersey, Van Houten & Prospect Sts., Paterson, N. J.

DA COSTA, ANTONIO M., Professor of Physics & Chemistry, "Escola Normal" & Instituto Polytechnico; res., Rua Pedro Ivo No. 8, Florianopolis, Edo. Sta. Catharine, Brazil, S. A.

DAVIS, JAMES LAWRENCE, Central Office Inspector, Western Electric Company, 401 Hudson St., New York; res., 55 Hanson Place, Brooklyn, N. Y.

DAWSON, CECIL, Research Assistant, Development Laboratory, General Electric Co., Ltd., Witton; res., 15 George Road, Erdington, Birmingham, Eng.

DE MELLO EUSTAGIO G., Cappella, Estado de Alagoas, Brazil, S. A.

DENNISON, WILLIAM O., Electrician, 56 W. Main St., Southbridge, Mass.

DE NUNZEO, FRANK, 317 Second Ave., New York, N. Y.

DE SOUZA, JACY T., Engineer & Director, de Viacao e Obras Publicas, State of St. Catharina; res., Rua Viscaude de Ouro Preto No. 39, Florianapolis, Edo St. Catharina, Brazil, S. A.

DESPRES, JOSEPH A., Engineering Dept., United Electric Light & Power Company, 130 E. 15th St.; res., 101 W. 80th St., New York, N. Y.

DONNELLY, JOSEPH B., Assistant Electrical Engineer, City of Philadelphia, 1211 Chestnut St.; res., 4028 Aspen St., Philadelphia, Pa.

DUEHNE, HERMAN, JR., Draughtsman, New York Edison Company, 15th St. & Irving Place; res., 266 E. 162nd St., New York, N. Y.

DUNCAN, HAMILTON A., Electrical Foreman, Phoenix Utility Company, Hauto, Pa.

EDDY, HERBERT GRIFFIN, Telephone Engineer, Western Electric Company, 463 West St., New York; res., 622 Bergen Ave., Jersey City N. J.

EELLS, M. MERWIN, Senior Partner, Eells & Hiney, 702 Montana Ave., S. Milwaukee, Wis.

ELGIN, CHARLES PORTER, Repeater Attendant, Princeton Station, American Tel. & Tel. Company; res., 50 Maple St., Princeton, N. J.

ELLSWORTH, WILLIAM CLARENCE, Long Lines Engineering Dept., American Tel. & Tel. Company, 195 Broadway, New York, N. Y.

ENNIS, DONALD A., Assistant General Foreman, Testing Dept., General Electric Company; res., 3 Livingston Ave., Schenectady, N. Y.

EVANS, CLAIR O., Assistant Secretary, British American Metals Company, 200 Broadway, New York, N. Y.

FAVARO, THOMAS., 28 Concord St., Jersey City, N. J.

FEAR, HAROLD JACKSON, Assistant Electrical Engineer, Elevator Supplies Company, Inc., 1515 Willow Ave., Hoboken, res., 12 Munn St., Montclair, N. J.

FINCH, WILLIAM GEORGE H., Radio Engineer, International News Service, World Bldg., New York, N. Y.

FORMAN, JOHN SIDNEY, Efficiency Engineer, Venice Power Station, Illinois Traction Company, Venice, Ill; res., 4534 Margaretta Ave., St. Louis, Mo.

FOSTER, WILLIAM CHAPMAN, Cadet Engineer, Public Service Electric Company, 80 Park Place, Newark, N. J.

GASSAWAY, CROSBY MITCHELL, Engineer, N. C. State Highway Commission, Sylva, N. C.

GEORGE, EARL BARCLAY, Designing Engineer, General Electric Company, Ft. Wayne, Ind.

GERDIN, OLAF, GOFDRIED, Engineer, Estimator, Economics Division, Interbrough Rapid Transit Company, 600 W. 59th St., New York. N. Y.

GEUE, JOHN E., Testing Dept., General Electric Company, res., 360 Summit Ave., Schenectady, N. Y.

GLINES, ROLAND B., Proprietor & General Manager, Roland B. Glines, 21 Oxford St., Lawrence, Mass.

GOODMAN, JOHN M., Switchboard Operator, New York Edison Company, 327 Rider Ave., res., 416 W. 122nd St., New York, N. Y.

GRANT, RICHARD J., Inspector, Public Service Company of Northern Illinois, 911 Church St., Evanston, Ill.

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GREEN, WALTER B., Engineering Dept., Mountain States Tel. & Tel. Company; res., 1733 S. Logan, Denver, Colo.

GRIFFEN, CHARLES D., Chief Inspector, Electric Distribution Dept., Westchester Lighting Company, Mt. Vernon; res., 184 Ashford Ave., Dobbs Ferry, N. Y.

GRIFFITH, CHARLES, Assistant to Director, University of Pennsylvania, Light & Heat Station; res., 2820 Boudinot St., Philadelphia, Pa.

GUILLAN, MANUEL, 67 Allen St., San Juan, P. R.

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HAGGERTY, DAVID DANIEL, Commercial Engineer, Western Electric Company, 463 West St., New York; res., 94 N. Oxford St., Brooklyn, N. Y.

HARRIS, BENJAMIN MORRIS, Winchester Repeating Arms Company; res., 52 Howe St., New Haven, Conn.

HARTY, EDGAR A., 18 E. 41st St., New York, N. Y.

HERRICK, CARL JAMES, Chief Electrician, Lehigh Portland Cement Company, Oglesby, Ill.

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HEWETT, ROGER SHERMAN, Engineering Assistant, New York & Queens Electric Light & Power Company, Bridge Plaza, Long Island City; res., 419 W. 118th St., New York, N. Y.

HEYDEN, ADOLF OTHMAR, Telephony Engineering, New York Telephone Company, 104 Broad St., New York; res., 149 Montgomery Ave., Irvington, N. J.

HILL, EDWARD PERCY, Plant Engineering Dept., Metropolitan Vickers Electric Co., Trafford Park, Manchester, Eng.

HOFFMANN, HENRY LOUIS, Equipment Engineer, International Western Electric Company, 463 West St., New York, N. Y.

HOLLAR, W. CARTER, Electrical Dealer & Contractor, 51-55 E. King St., Shippensburg, Pa.

HOLLNAGEL, HERBERT PERCIVAL, Physicist in charge, Dept. of Physical Engineering & Research, Thomson Research Laboratory, General Electric Co., Lynn; res., 22 Hampden St., Swampscott, Mass.

HOLMES, FREDERICK, Secretary, Duncan Electric Mfg. Company, Lafayette, Ind.

HOMES, JACK, Electrician, Gallup American Coal Company, Gibson, New Mexico.

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HOWE, KASSON, Electrical Engineer, Ward Leonard Electric Company, Mt. Vernon; res., Weaver St., Larchmont, N. Y.

HOYT, FANNING O., Manager, Standard Underground Cable Company, North American Bldg., Philadelphia, Pa.

HUMMLER, AUGUST, Foreman, Repair Shop, I. Stark Company, Inc., 346 Tomkins Ave., Brooklyn; res., 79 Hilldale Ave., Jamaica, N. Y.

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INADA, SANNOSUKE, Chief Engineer, Dept. of Communication of Japan, Tokyo, Japan; Mitsui & Company, 65 Broadway, New York, N. Y.

INGALLS, ROSS DARWIN, Designing Electrical Engineer, Diehl Mfg. Company, Elizabeth, N. J.

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*ISAACSON, CHARLES BYRON, Electrical Engineer, All America Cables, New York, N. Y.; Barranco, Lima, Peru.

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KALLEY, OSCAR, Electrical Designer & Checker, Stone & Webster, 147 Milk St., Boston; res., 35 Center St., Holbrook, Mass.

KAY, THOMAS, Electrician, West Penn Power Company; res., 148 S. Wade Ave., Washington, Pa.

KENNEDY, WILLIAM F., General Foreman, Meter & Test Depts., New York & Queens Electric Light & Power Co., Long Island City; 46 Lawrence St., Flushing, N. Y.

*KINGSLEY, NORMAN W., Division Interference Engineer, Northwestern Bell Telephone Company, 122 S. 6th St., Minneapolis, Minn.

KINLOCK, WILLIAM H., Telephone & Lighting Engineer, Interborough Rapid Transit Company, 165 Broadway; res., 21 Cleveland St., New Brighton, N. Y.

KNOEPKE, WILLIAM LOUIS, Engineer, Western Electric Company, Inc., 463 West St., New York; res., 122 N. Fulton Ave., Mt. Vernon, N. Y.

KOCHHAR, BISHAN DASS, State Electrical Engineer, Rampur State, U. P. India.

*LA MONTAGNE, LESLIE H., Statistician, Pacific Gasoline Company, Taft, Calif.

LEAVENS, ERIC, Engineering Assistant, Traffic Dept., Western Union Tel. Co., 195 Broadway, New York, N. Y.

LEUVELINK, BERNARD, Specification Engineer, Western Electric Company, 463 West St., New York, N. Y.; res., 1046 Madison Ave., Paterson, N. J.

LEWIS, CHARLES HENRY, Assistant Division Superintendent, Public Service Electric Company, 323 Palisade Ave., Jersey City, N. J.

LOFTUS, PETER FRANCIS, Electrical Engineer, New York World's Interests; Le Grasse Paper Company, Pyrites; res., 30 Pickering St., Ogdensburg, N. Y.

LOVE, JOHN S., Division Storage Battery Inspector, Wisconsin Telephone Company; res., 483 Park Place, Milwaukee, Wis.

LYONS, GEORGE E., Acting Foreman, Electric Traction, Pennsylvania Railroad Company, 4th & Front Sts., Long Island City; res., 447 Woodland Ave., Woodhaven, N. Y.

MacCALLUM, ALEXANDER F., District Service Manager, Westinghouse Elec. & Mfg. Company, 1909-15 Blake St., Denver, Colo.

MacDONALD RODERICK NORMAN DOUGLAS, Operator, The Ontario Paper Company, Thorold; res., Port Dalhousie, Ont.

MacMICHAEL, HUGH NEIL, Instructor, Leeds & Northrup Company, Germantown; res., 1934 N. Judson St., Philadelphia, Pa.

McCABE, JOHN H., Sales Clerk, Westinghouse Elec. & Mfg. Company, 1062 Gas & Electric Bldg., Denver, Colo.

McCARTY, GEORGE MARTIN, Telephone Engineer, American Telephone & Telegraph Company, 195 Broadway, New York, N. Y.

McKINLEY, HENRY C., Electrical Inspector, The Hartford Steam Boiler Inspection & Insurance Company, 100 William St., New York; res., 329 Richmond Ave., Port Richmond, N. Y.

MEINEKE, OTTO HENRY, Chief Electrician, Standard Seamless Tube Company, Ambridge, Pa.

MEYEROWITZ, PAUL R., 132 W. 88th St., New York, N. Y.

*MILLER, ANDREW LINCOLN, Instructor, Electrical Engineering, University of Michigan, Ann Arbor, Mich.

MILNE, IRVING J., Senior Load Dispatcher, New York & Queens Electric Light & Power Company; res., 426 Sherman St., Long Island City, N. Y.

MITCHELL, WILLIAM HENRY, Electrician, U. S. Navy, U. S. S. N-2, Submarine Base, New London, Conn.

MOORE, DANIEL E., Equipment Engineer, Illinois Bell Telephone Company, 212 W. Washington St.; res., 1510 W. 104th St., Chicago, Ill.

MORRIS, ROLLO CROFFORD, Assistant Distribution Engineer, Union Electric Light & Power Company, 315 N. 12th St., St. Louis, Mo.

*MULLER, JOHN HENRY, JR., Engineer, Power Plant Dept., New York Telephone Company, 104 Broad St., New York; res., 229 Mt. Pleasant Ave., Newark, N. J.

MUSSEN, WILLIAM, Testing Dept., Electric Products Company; res., 7204 Memphis Ave., Cleveland, Ohio.

NELSON, PETER RAYMOND, Salesman, Edison Storage Battery Company, 1902 N. Charles St., Baltimore, Md.

NELSON, WALTER KENNETH, Instructor, Engineering Mathematics, University of Colorado, Boulder, Colo.

OLIVER, ROBERT B., Sales Manager, Bryan-Marsh Division National Lamp Works, 4622 Grand Central Terminal, New York, N. Y.

ONARHEIM, JAMES I., Draftsman, Allis-Chalmers Mfg. Company, 1527 Fond du Lac Ave., Milwaukee, Wis.

O'ROARK, LAUREN SNYDER, In charge, Engineering Service Dept., Western Electric Company, Inc., New York; res., Mt. Kemble Ave., Morristown, N. J.

OSBORNE, THOMAS A., Plant Chief, Mountain States Tel. & Tel. Company, 56 S. State St., Salt Lake City, Utah.

PAMPIN, JUAN, Chief Electrician, S. A. Fabrica Argentina de Alpargata s, Buenos Aires; res., Calles 6 No. 321, La Plata, Argentine Republic, S. A.

*PARDEE, STARR CARLTON, Engineering Dept., Pacific Gas & Electric Company, San Francisco, Cal.

PARKER, GEORGE BLAINE, Long Lines Engineering Dept., American Tel. & Tel. Company, 195 Broadway, New York, N. Y.

PATTON, WILLIAM CHARLES, British General Electric Company, 257 Clarence St., Sydney, N. S. W., Australia.

PAVEY, FRANCIS LEE, Assistant Sales Manager, Duncan Electric Mfg. Company; res., 14 S. 9th St., Lafayette, Ind.

PAYNE, BURTON R., Meter Superintendent, Depew & Lancaster Light, Power & Conduit Company; res., 50 Court St., Lancaster, N. Y.

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POEY, CHARLES DOWNING, Illuminating Engineer, New York & Queens Electric Light & Power Company, Electric Bldg., Long Island City, N. Y.

PYE, HARRY A., Engineer, New England Tel. & Tel. Company, 50 Oliver St., Boston; res., 616 Sumner St., Arlington, Mass.

PYLE, WILLIAM FRANKLIN, Sales Manager, Duncan Electric Mfg. Company; res., 821 S. 12th St., Lafayette, Ind.

REDD, JOHN C., Westinghouse Elec. & Mfg. Company; res., 408 Franklin Ave., Wilkinsburg, Pa.

REED, RUSSELL M., Power Plant Construction, New York Telephone Company, 227 E. 30th St., New York, N. Y.; res., 127 Summit Ave., Jersey City, N. J.

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RICHARDSON, H. LEONARD, Wire Rope Engineer, Sales Dept., American Steel & Wire Company, 1204 Brown Marx Bldg., Birmingham, Ala.

*RICK, GEORGE DEWEY, Student, School of Engineering of Milwaukee; res., 143-4th St., Milwaukee, Wis.

ROBERTS, LEROY C., Assistant Foreman, Meter & Test Dept., The United Electric Light & Power Co., 514 W. 147th St., New York; res., 216 Fenimore St., Brooklyn, N. Y.

ROGERS, HURLEY T., Estimator, New York & Queens Electric Light & Power Company, Electric Bldg., Bridge Plaza; res., 31 Ely Ave., Long Island City, N. Y.

RUBYOR, HAROLD EDWARD, Instructor, Practical Electricity, K. C. School for Ex-Service Men; Inspector, Light & Power, Dept. of Water Supply, Gas & Electricity; res., 455 E. 163rd St., New York, N. Y.

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SANDERS, JOSEPH BISHOP, Telephone Systems Development Engineering Dept., Western Electric Company, 463 West St., New York, N. Y.; res., 563 William St., E. Orange, N. J.

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*SEYFERLICH, WALTER MILTON, Testing Engineer, Republic Flow Meters Company, 2240 Diversey Blvd.; res., 439 Wrightwood Ave., Chicago, Ill.

SHAEFER, EARL A., Engineering Dept., General Electric Company; res., 1126 Jones St., Ft. Wayne, Ind.

SHUTT, EDWIN HOLMES, District Sales Agent, Standard Underground Cable Company, 1182 Arcade Bldg., St. Louis, Mo.; res., 4217 Locust St., Kansas City, Mo.

SHWAB, THOMAS CARLYLE, Engineering Assistant, New York & Queens Electric Light & Power Co., Bridge Plaza, L. I. City; res., 166 Rutland Road, Brooklyn, N. Y.

*SIEFRIED, JOSEPH ALBERT, Switchboard Operator, Pennsylvania Power & Light Co., Allentown; res., 208 S. Main St., Nazareth, Pa.

SIEGL, A., General Equipment Foreman, Wisconsin Telephone Company, Milwaukee; res., 157 Aetna Court, Wauwatosa, Wis.

SIMSON, GEORGE FRANCIS, Electrical Design Draftsman, Hydro-Electric Power Commission, 190 University Ave., Toronto, Ont.

*SKOOGLAND, CARL MARTIN, Engineer, West Penn Power Company; res., 218 N. Craig St., Pittsburgh, Pa.

SLATTERY, THOMAS F., Draftsman, Denver & Interurban Railroad Company; res., 3329 W. 25th Ave., Denver, Colo.

*SOVIK, ROBERT A., Testing Dept., United Light & Power, New York; 537 W. 147th St., 16 North Terrace Ave., Mt. Vernon, N. Y.

STAIR, DICKINSON H., Line Foreman, Braden Copper Co., Rancagua, Chile, S. A.

STELLGER, HENRY JOHN, Assistant Electrical Engineer, Elevator Supply & Repair Company, 1515 Willow Ave., Hoboken; res., 73 Parkway East, Bloomfield, N. J.

STEVENS, PERCY EDWARD, Assistant Engineer, Messrs, Ironside Son & Co., Calcutta, India.

STOSKOPF, LOUIS N., Service Supervisor, American Tel. & Tel. Company, 195 Broadway, New York, N. Y.

TALLMAN, WILLIAM JOHN, Inside Telephone Man, New York Telephone Company, 15 Dey St., New York; res., 105 Pioneer St., Brooklyn, N. Y.

TAYLOR, JOHN D., Division Transmission Engineer, Northwestern Bell Telephone Company; res., 5052 Washburn Ave., S. Minneapolis, Minn.

THOMAS, WALTER STANLEY, Chief of Photometer Dept., Osram-General Electric Company Lamp Works, Brook Green, Hammersmith; res., 39 Dover House Road, Putney S. W., 15, London, Eng.

*TJIATTAS, ANASTASSIOS CONSTANTIN, Fieldman, Underground Division, Duquesne Light Co., Pittsburgh; res., 316 Rebecca Ave., Wilkinsburg, Pa.

*TRUMBULL, ARTHUR JOHN, Inspector, Brooklyn Edison Company, Inc., 14 Rockwell Place, Brooklyn, N. Y.; res., 317 Pavonia Ave., Jersey City, N. J.

VAN DEUSEN, GEORGE L., Major, U. S. A. Camp Alfred Vail, N. J.

VAN ETSEN, LEO A., Electrical Contractor, 56 W. 37th St.; res., 808 West End Ave., New York, N. Y.

VAN ROSEN, HUGO, Partner, New England Manager, Delta Star Electric Co.; Bates Expanded Steel Truss Co., Room 628 Old South Bldg., Boston, Mass.

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WILKIE, DAVID F., Foreman Electrician, Tempe, Ariz.

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WILLIAMS, JOSEPH, Switchboard Dept., Westinghouse Elec. & Mfg. Company, 467 10th Ave.; res., 2432 University Ave., New York, N. Y.

WILLIS FREDERICK CHARLES, Designing Engineer, Western Electric Company, 463 West St., New York; res., 102 Bard Ave., West Brighton, S. I., N. Y.

WILSON, HERBERT W., Salesman, Erner Electric Company, 1240 Ontario St., Cleveland, Ohio.

WOLFE, LESTER, Engineer, Delta Engineering Company, 110 W. 40th St.; res., 923 Fox St., New York, N. Y.

YOUNG, FRED A., Foreman, Interior Construction, New York & Queens Electric Light & Power Company, Bridge Plaza; res., 389 Sherman St., Astoria, Long Island City, N. Y.

ZEISS, ANTHONY, Draftsman, Western Electric Company, Inc., 463 West St.; res., 546 E. 182nd St., New York, N. Y.

ZIEGLER, ADOLPH L., Switchboard Wireman, Westinghouse Elec. & Mfg. Company; res., 408 Franklin Ave., Wilkinsburg, Pa.

Total 191.

*Formerly Enrolled Students.

ASSOCIATES REELECTED APRIL 11, 1922

EAVES, AUGUSTUS JACKSON, Telegraph Engineer, Western Electric Company, Inc., 463 West St., New York; res., 31 Belleview Ave., Ossining, N. Y.

MEYER, HANS JULIUS, President, Charles L. Pillsbury Company, 1200 2nd Ave., S., Minneapolis, Minn.

RUDISILL, WESLEY HAVEN, Chief Engineer, Richmond Light & Railway Company, Terminal Bldg., New Brighton, N. Y.

THAYER, EDWARD SPRAGUE, Electrical Engineer, Skagit River Power Project, 1401 Alaska Bldg., Seattle, Wash.

MEMBERS REELECTED APRIL 11, 1922

CONNELL, HARVEY FRANCIS, Engineer, Semet-Solvay Company, Syracuse; res., Sunset Terrace, Baldwinsville, N. Y.

HULSE, WILLIAM STEWART, Member of Firm, Wood, Hulse, Yates Company, 233 Broadway, New York, N. Y.

MEMBERS ELECTED APRIL 11, 1922

CHARLESWORTH HARRY PRESCOTT, Plant Engineer, American Tel. & Tel. Company, 195 Broadway, New York, N. Y.

GOWEN, ROBERT FELLOWS, Engineer, De Forest Radio Tel. & Tel. Co.; res., Ossining-on-Hudson, N. Y.

HARLOW, JOHN B., Electrical Engineer, Western Electric Company, 463 West St., New York, N. Y.

HOLGERS, ERNEST Z. N., Engineer, Dwight P. Robinson & Company, 125 E. 46th St., New York, N. Y.

KUHN, GEORGE W., Engineer, M. R. Maltbie, 177 Broadway, New York, N. Y.

LA DUE, WILLIAM ALEXANDER, Division Superintendent, Public Service Electric Co., 323 Palisade Ave., Jersey City, N. J.

MOLINA, EDWARD C., Electrical Engineer, Dept. of Development & Research, American Tel. & Tel. Company, 195 Broadway, New York, N. Y.

PORTER, SETON, Partner of Firm, Sanderson & Porter, 52 William St., New York, N. Y.

QUAYLE, FREDERICK RICHARD, Assistant Superintendent of Equipment Engineering, Automatic Electric Company, 947 W. Van Buren St., Chicago, Ill.

STACY, LELAND JOHNSON, Engineer, Western Electric Company, Inc., 463 West St., New York, N. Y.

STEPHENS, CHARLES E., Division Manager, Sales Dept., Westinghouse Electric & Mfg. Company, 165 Broadway, New York, N. Y.

STOTT, ROBERT A., Assistant to Electrical Engineer, United Electric Light & Power Company, 130 E. 15th St., New York, N. Y.

WIDMER, JULES A., Development Engineer, Square D Company, 6060 Rivard St., Detroit, Mich.

TRANSFERRED TO GRADE OF FELLOW APRIL 11, 1922

NORTON, WILLIAM J., Member of Firm, Norton, Bird & Whitman, Newark, N. J.

TRANSFERRED TO GRADE OF MEMBER APRIL 11, 1922

BOYRER, WILLIAM C., Electrical Engineer, Public Service Commission, New York, N. Y.

DILL, GEORGE C., Designing Electrical Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

HARSEIM, HENRY W. V., Pangborne & Co., Philadelphia, Pa.

ROBERTS, DOUGLAS A., General Supt., Southern Illinois Railway & Power Co., Harrisburg, Ill.

STEIN, HERMAN K., Supt. & Electrical Engineer, Genesee Light & Power Co., Batavia, N. Y.

WEBB, LEWIS W., Master Electrician, U. S. Navy Yard, Norfolk, Va.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held April 10, 1922, recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Fellow

HARRIES, GEORGE H., Vice-President, Bylesby Engineering & Management Corp., Chicago, Ill.

ROBINSON, CHARLES A., Chief Engineer, Chesapeake & Potomac Telephone Co., Washington, D. C.

SWOPE, GERARD, President, International General Electric Co., Schenectady, N. Y.

To Grade of Member

ABBOTT, WILLIAM R., President, Illinois Bell Telephone Co., Chicago, Ill.

ALGER, PHILIP L., Electrical Engineer (Designing), General Electric Co., Schenectady, N. Y.

BROPHY, JOHN J., Electrical Engineer, Turner Tanning Machinery Co., Peabody, Mass.

CALDWELL, O. H., Editor, *Electrical Merchandising*, New York, N. Y.

COUP, FRED T., District Manager, Wagner Electric Mfg. Co., Cincinnati, O.

DORTING, E. E., Lighting Engineer, Interborough Rapid Transit Co., New York, N. Y.

FERRARI, CHARLES, Technical Manager, Societe Meridionale di Electricita, Naples, Italy.

FOWLER, MYRON M., Electrical Engineer, General Electric Co., Chicago, Ill.

FOX, WILLIAM A., Vice-President, Commonwealth Edison Co., Chicago, Ill.

GIERSCH, RICHARD F., JR., Construction Engineer, Cleveland Mill & Power Co., Lawndale, N. C.

HIGMAN, H. LAWTON, Divisional Maintenance Supt., Ebro Power Co., Barcelona, Spain.

HOBBINS, WILLIAM D., Chief Engineer, Wisconsin Telephone Co., Milwaukee, Wis.

LANPHIER, BASIL, Electrical Research Engineer, Interborough Rapid Transit Co., New York, N. Y.

LITTLER, RAYMOND G., Owner and Manager, West Coast Engineering Co., Portland, Ore.

PERRY, CHARLES T., Electrical Engineer, City Department of Plant and Structures, New York, N. Y.

PLACE, CLAUDE W., Engineer, General Electric Co., Chicago, Ill.

POUPART, ERNEST, Electrical Engineer, Lake Shore Mines, Ltd., Kirkland Lake, Ont.

TRUESDELL, JAMES W., General Manager, Electric Contractors Corp., Waterbury, Conn.

TUCKER, JESSE O., Supt. of Overhead, St. Louis Electric Terminal Ry. Co., St. Louis, Mo.

WELGE, D., Chief Electrical Engineer, Bluestone Mining & Smelting Co., Mason, Nev.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute, the list indicating the geographical district and Section in which the applicant is at present located. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before May 31, 1922.

Geographical District No. 1

Boston Section

Gillard, William A., Boston, Mass.
Goodrich, Albert S., (Member), Boston, Mass.
Knudsen, H. A., Boston, Mass.
Nelson, Oscar W., Boston, Mass.
Sproul, Walton D., Hanover, Mass.
Wang, Meng, Cambridge A., Mass.

Connecticut Section

Bauer, John H., Hartford, Conn.
Lewis, Charles G., (Member), New Haven, Conn.
Lutsey, Samuel F., Hartford, Conn.
Lynge, Carl M., (Member), Bridgeport, Conn.
McElhone, Benjamin H., New Haven, Conn.
Russell, Thomas J., New Haven, Conn.
Scott, Walter W., New Haven, Conn.

Lynn Section

Eynon, Stuart J., Lynn, Mass.
Herbert, Clinton T., Lynn, Mass.
Moody, B. Frank, Lynn, Mass.
Pomeroy, Llewellyn D., Andover, Mass.
Seigle, William B., Lynn, Mass.
Stevens, George M., Lynn, Mass.
Twiss, Paul E., W. Lynn, Mass.

Providence Section

Southworth, Herbert, Providence, R. I.

Rochester Section

Ely, George G., Rochester, N. Y.
Vogt, Harry E., Rochester, N. Y.

Schenectady Section

Bacon, Charles A., Amsterdam, N. Y.
Cameron, Donald L., Schenectady, N. Y.
Harrington, Elliott D., Schenectady, N. Y.
Johnson, J. Ralph, Schenectady, N. Y.
Manning, Robert S., Little Falls, N. Y.
Peabody, George A., Schenectady, N. Y.
Winfield, Frederick C., Schenectady, N. Y.

Non-Section Territory

Burnes, George W., Buffalo, N. Y.
Garnjost, Frank W., Niagara Falls, N. Y.
Williams, George S., (Fellow), Augusta, Me.
Total 33.

Geographical District No. 2

Baltimore Section

Lindley. Albert H., Baltimore, Md.

Cincinnati Section

Bentley, Frank H., Dayton, Ohio
Burns, Harry R., Cincinnati, Ohio
Bushnell, Samuel K., Dayton, Ohio
Harned, Mark L., Cincinnati, Ohio
Horne, George R., Cincinnati, Ohio
Liebenberg, Arthur J., (Member), Cincinnati, Ohio
McKinley, Glen L., Cincinnati, Ohio

Cleveland Section

Blumel, Anthony, Cleveland, Ohio
Frazier, Edward C., Cleveland, Ohio
Gudmens, H. William, Cleveland, Ohio
Hlava, Adolf V., Elyria, Ohio
Iden, Reuben D., Elyria, Ohio
Kelley, Helen, Cleveland, Ohio

Philadelphia Section

Austin, Harvey B., Philadelphia, Pa.
Gittelman, Henry A., Reading, Pa.
Hires, J. Edgar, Langhorne, Pa.
Lynch, William O., Camden, N. J.
Marshall, Harry B., (Member), Philadelphia, Pa.
Norton, Benjamin R., Philadelphia, Pa.
Prenner, I. S., (Member), Philadelphia, Pa.
Schwenk, Abram B., Philadelphia, Pa.
Weinberg, Philip H., Philadelphia, Pa.
Wilson, John E., Philadelphia, Pa.

Pittsburgh Section

Borland, James E., Pittsburgh, Pa.
Butcher, Charles A., (Member), E. Pittsburgh, Pa.
Einstein, Raymond H., Blairsville, Pa.
Grandin, Franklin G., Tarentum, Pa.
Jeffers, Howard W., Pittsburgh, Pa.
Johnston, Lloyd E., Pittsburgh, Pa.
McElroy, George S., Pittsburgh, Pa.
Miller, Paul E., Greensburg, Pa.
Muntz, Richard, Butler, Pa.

Washington, D. C. Section

Columbus, Adolphe E., Washington, D. C.
Dettra, Paul R., Washington, D. C.

Non-Section Territory

Albin, Henry A., Lebanon, Pa.
Jones, Russell N., Johnsonburg, Pa.
Lamb, E. Blair, Mullens, W. Va.
Total 38.

Geographical District No. 3

New York Section

Arland, Frederick L., New York, N. Y.
Babcock, Robert, Brooklyn, N. Y.
Balch, Elwyn C., New York, N. Y.
Battle, Robert T., New York, N. Y.
Blanchard, Nathaniel W., New York, N. Y.
Buss, Russell S., New York, N. Y.
Caldwell, George W., New York, N. Y.
Charlton, John R., New York, N. Y.
Coutts, Harold L., Perth Amboy, N. J.
Druliner, Frank L., Brooklyn, N. Y.
Farrugia, Joseph M., New York, N. Y.
Gillette, Claude S., (Member), New York, N. Y.
Gonzalez, Malcolm J., Brooklyn, N. Y.
Gugenbul, Roger W., New York, N. Y.
Harvey, Francis W., (Member), New York, N. Y.
Hines, John W., New York, N. Y.
Kahle, Louis C., Union Hill, N. J.
Kinnaman, P. Powers, Newton, N. J.
Lane, Clarence E., New York, N. Y.
Lattimer, Irving E., New York, N. Y.
Lutz, William E., New York, N. Y.
Martin, Burney K., New York, N. Y.
McDermott, William J., Long Island City, N. Y.
Morgan, Joseph M., Brooklyn, N. Y.
Morse, George H., (Fellow), New York, N. Y.
Rowe, Fred K., New York, N. Y.
Seichter, Max, New York, N. Y.
Urban, John E., Perth Amboy, N. J.
Van Vleet, Arthur K., New York, N. Y.
Weed, Irving, New York, N. Y.
Zeuthen, Ernst, Brooklyn, N. Y.

Non-Section Territory

Manning, Leon J., Central Tanamo, Cayo Mambi, Oriente, Cuba
Total 32.

Geographical District No. 4

Non-Section Territory

Butler, Frank A., Memphis, Tenn.
Dulen, William S. Gordon, Richmond, Va.
Rockett, John F., Hartsville, S. C.
Total 3.

Geographical District No. 5

Chicago Section

Bracken, Ellis F., (Member), Chicago, Ill.
Burrell, Eugene J., Chicago, Ill.
Douglas, A. W., Chicago, Ill.
Glueck, Bruno, Chicago, Ill.
Norton, Edward J., Chicago, Ill.

Detroit Section

Baker, J. A., Detroit, Mich.
Harza, Carl W., Detroit, Mich.
Himes, Lake W., Detroit, Mich.

Fort Wayne Section

Upp, Charles B., Ft. Wayne, Ind.
Valentine, Forrest C., Ft. Wayne, Ind.

Madison Section

DeWire, Donald S., Madison, Wis.
Hayes, Leslie E., Madison, Wis.
Metcalf, Earle S., Janesville, Wis.

Milwaukee Section

Rice, Alexander E., Milwaukee, Wis.
Tschernitz, Frank, Milwaukee, Wis.
Wolff, Adolph F., Milwaukee, Wis.

Urbana Section

Burkhart, Paul H., Urbana, Ill.

Non-Section Territory

Huller, Floyd C., Dowagiac, Mich.
Total 18

Geographical District No. 6

Denver Section

Yelton, Frank H., Denver, Colo.

Non-Section Territory

Edwards, Edward D., Lander, Wyoming
Jewett. Clarence G., Keokuk, Iowa
Peak, Earl N., (Fellow), Marshalltown, Iowa
Porter, James H., Oskaloosa, Iowa
Tedberg, Ernest J., (Member), Pembina, N. D.
Total 6.

Geographical District No. 7

Kansas City Section

Bettis, Alexander E., Kansas City, Mo.
Jenkins, Forrest O., Kansas City, Mo.
Smith, Ferral D., Richmond, Mo.

Oklahoma Section

Barner, John H., Cushing, Okla.

St. Louis Section

Clarke, Oliver H. P., (Member), St. Louis, Mo.

Non-Section Territory

Blamey, Chester A., (Member), Hot Springs, Ark.
Total 6.

Geographical District No. 8

Albert, Norman M., San Francisco, Cal.

San Francisco Section

Dodge, Warren T., Oakland, Calif.
Johnson, Alfred R., Modesto, Calif.
Marsh, David G., (Member), San Francisco, Cal.

Non-Section Territory

Buchanan, George A., Phoenix, Ariz.
Cayot, Ramon, Alta, Calif.
Moulton, James S., Fresno, Cal.
Total 7.

Geographical District No. 9

Portland Section

Hoff, Oliver C., Portland, Ore.
Sibley, Donald V., Portland, Ore.
Stevey, C. F., Camas, Wash.

Seattle Section

Ahrens, William E., Seattle, Wash.
Anderson, Frans I., Sultan, Wash.
Rasmussen, Carl J., Seattle, Wash.
Smith, Ralph W., (Member), Tacoma, Wash.

Utah Section

Beck, Theo. W., Ogden, Utah
Douglas, Howard H., Rupert, Idaho
Miller, Howard C., (Member), Preston, Idaho
Scotness, Christian, Diamondville, Wyoming
Scott, William M., (Member), Salt Lake City, Utah
Wilson, Fred W. J., Salt Lake City, Utah

Non-Section Territory

Currin, H. P., Baker, Oregon
Total 14.

Geographical District No. 10

Toronto Section

Atherton, Harold, Hamilton, Ont.
Baker, Frederick K., Niagara Falls, Ont.
Briggs, John B., Dalhousie Lake, Ont.
Code, Francis L., Niagara Falls, Ont.
Culver, Charles A., (Fellow), Toronto, Ont.
Dancy, Wilfrid A., Toronto, Ont.
Edgar, Arthur S., Toronto, Ont.
Gray, Guy A., Niagara Falls, Ont.
Hubbert, Sydney J., Toronto, Ont.
Hyatt, George H., Toronto, Ont.
Jory, Walter J., Toronto, Ont.
Lawson, John E., Niagara Falls, Ont.
Mabon, Roy W., Niagara Falls, Ont.
Peters, George, Toronto, Ont.
Potts, George, Toronto, Ont.
Rowntree, Fred W., Weston, Ont.
Teckoe, John E., Niagara Falls, Ont.

Vancouver Section

Hall, Richard L., (Member), Vancouver, B. C.
Larssen, Edward O., Vancouver, B. C.
Lloyd, Herbert M., (Member), Vancouver, B. C.
McGuire, George T., (Member), Vancouver, B. C.
Marcus, Reginald C., Trail, B. C.
McDonald, Alexander E., Trail, B. C.
Northrop, J. H., Vancouver, B. C.
Total 24.

Total Applications Received 181.

FOREIGN

Bunnetta, George A., Bombay, India
Combes, Frank R., Erdimgton, Birmingham, Eng.
Golden, Marcel M., Paris, France
Holbeach, Constantine H., London, Eng.
Ito, Teiji, Sendai, Japan
Noerr, Leonard, Suva, Fiji, Fiji Islands
Olson, Harry J., Stockholm, Sweden
Rhymes, James, Hyde, Cheshire, Eng.
Takenouchi, Takashi, Nagoya, Japan
Yusuf, Mohammed L. S., Deccen, India
Total 10.

STUDENTS ENROLLED APRIL 11, 1922

14898 Blanding, William H., University of North Dakota
14899 McDowell, T. Edward, Armour Institute of Technology.
14900 Sloan, Arthur H., Armour Inst. of Tech.
14901 Hinz, Horace, New York Elec. School
14902 Falkanger, Norman S., University of North Dakota
14903 Ollinger, Clair F., New York Elec. School
14904 Wringandt, Howard C., Univ. of Wisconsin
14905 Holt, Homer W., University of Arizona
14906 Mathieu, Henry P., Rice Institute
14907 Fallon, Glover P., Johns Hopkins Univ.
14908 Powne, Norman Oregon State Agri. Coll.
14909 Reid, William J. W., University of Toronto
14910 Corwin. Thomas L.,Georgia School of Tech.
14911 Bullock, E. S., Georgia School of Tech.

14912 Mitchell, Thomas H., Georgia School of Technology
14913 England, John A., Georgia School of Tech.
14914 Wethington, Richard W., Georgia School of Technology
14915 Moore, Horace A., Georgia School of Tech.
14916 Torbett, Joseph L., Georgia School of Tech.
14917 Campbell, William J., Georgia School of Technology
14918 Perdue, A. M., Alabama Polytechnic Inst.
14919 Hendley, F. Joe, Alabama Polytechnic Inst.
14920 Kinzer, James H., Alabama Polytechnic Inst.
14921 Weaver, Wilbert M., Alabama Polytechnic Institute
14922 Spethmann, Glenn E., Univ. of Nebraska
14923 Clark, Lemore W., Univ. of Wisconsin
14924 Carter E. Finley, Rice Institute
14925 Dufault, John A., Worcester Polytechnic Institute
14926 Nesmith, James, 2nd, Mass. Institute of Technology
14927 Schumacher, Harold F., Newark Technical School
14928 Bass, Alexander H., Stevens Inst. of Tech.
14929 Eisemann, Arthur S., Villanova College
14930 Eisenmann, Robert J., Villanova College
14931 Bueche, Harry S., Villanova College
14932 Miller, Charles F., Tri-State College of Engineering
14933 Thomas, Ralph E., Pennsylvania State Coll.
14934 Lynn, James E., Municipal Univ. of Akron
14935 Prastka, Otto, Tri-State College of Engg.
14936 Pierce, Walter S., Tri-State College of Engg.
14937 Moor, Harvard E., Mass. Inst. of Tech.
14938 Goodrich, Dana C., Clarkson College of Technology
14939 Morse, Merton D., Union College
14940 Bowman, Percy F., State Univ. of Iowa
14941 Campbell, Robert W., Pennsylvania State College
14942 Powell, Albert P., Mass. Institute of Tech.
14943 Francis, James F., Cornell University
14944 March, Alfred H., Jr., Cornell University
14945 Warren, Robert D., Cornell University
14946 Stone, John R., Cornell University
14947 Quinn, George E., Cornell University
14948 Brittain, R., Cornell University
14949 Daniel, Laurence H., Cornell University
14950 Tevonian, H. P., Cornell University
14951 Luque, Eduardo D., Cornell University
14952 Pollard, George M., Cornell University
14953 Jenks, Stephen M., Cornell University
14954 Tewksbury, Floyd L., Cornell University
14955 Smith, Beauchamp E., Cornell University
14956 Williams, Roy S., Cornell University
14957 Cornell, Ezra, Cornell University
14958 Johnston, James W., Cornell University
14959 Nichols, William E., Iowa State College
14960 Richardson, Roscoe, Iowa State College
14961 Gould, William, Stevens Institute of Tech.
14962 Lucas, Henry A., New York Elec. School
14963 Morin, Charles B., Drexel Institute
14964 Packard, Charles A., Drexel Institute
14965 Pyle, W. A. Faries, Drexel Institute
14966 Ward, Alvin C., Univ. of Minnesota
14967 Dormer, William J. S., McGill University
14968 Ringold, H. Russell, Tri-State College of Engineering
14969 Offutt, Henry Y., Rose Polytechnic Inst.
14970 Allen, Thomas T., Drexel Institute
14971 Whittum, Charles H., Mass. Inst. of Tech.
14972 Simons, Elwin H., Wentworth Institute
14973 Malcomson, Robert, University of Illinois
14974 Leeming, Mason S., University of Illinois
14975 Halperin, Isadore M., Univ. of Illinois
14976 Smart, John W., University of Wisconsin
14977 Herrlein, Wesley R., Carnegie Institute of Technology
14978 Rauchfleisch, Bernard J., Tri-State College of Engineering
14979 Reid, William R., Pratt Institute
14980 Maihofer, Anton G., University of Mich.
14981 Castagno, Vincent J., New York Electrical School
14982 Gaynor, Joseph D. N., Catholic University of America
14983 Queen, George N., Catholic University of America
14984 Griffin, Philip H., Catholic University of America
14985 Haggerty, John J., Catholic University of America
14986 Lamb, James J., Catholic University of America
14987 Johnston, Donald F., Catholic University of America
14988 McCarthy, Charles F., Catholic University of America
14989 Briggs, William N., Tri-State College of Engineering
14990 Hyland, James F., Lowell Institute, School for Industrial Foremen
14991 Cravens, Russell C., Tri-State College of Engineering
14992 Bars, Carl, Tri-State College of Engineering.
14993 Hultgren, Harold I., Armour Institute of Technology

Total 96.

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WILLIAM McCLELLAN

Junior Past-Presidents

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W. A. DEL MAR	C. G. ADSIT
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GEORGE A. HAMILTON

Secretary
F. L. HUTCHINSON

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(A list of the personnel of Institute committees may be found in the January issue of the JOURNAL, and will be published again in the June issue.)

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EXECUTIVE, William McClellan
FINANCE, L. F. Morehouse
MEETINGS AND PAPERS, E. E. F. Creighton
PUBLICATION, A. S. McAllister
COORDINATION OF INSTITUTE ACTIVITIES, W. I. Slichter
BOARD OF EXAMINERS, H. H. Norris
SECTIONS, A. W. Berresford
STUDENT BRANCHES, C. Francis Harding
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HEADQUARTERS, W. A. Del Mar
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PUBLIC POLICY, H. W. Buck
CODE OF PRINCIPLES OF PROFESSIONAL CONDUCT, C. A. Adams
SAFETY CODES, H. B. Gear
STANDARDS, Harold Pender
EDISON MEDAL, C. A. Adams
RESEARCH, F. B. Jewett

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INDUSTRIAL AND DOMESTIC POWER, W. C. Yates
INSTRUMENTS AND MEASUREMENTS, F. V. Magalhaes
IRON AND STEEL INDUSTRY, E. S. Jefferies
LIGHTING AND ILLUMINATION, G. H. Stickney
MARINE, Arthur Parker
MINES, Graham Bright
POWER STATIONS, R. F. Schuchardt
PROTECTIVE DEVICES, H. R. Woodrow
TELEGRAPHY AND TELEPHONY, Donald McNicol
TRACTION AND TRANSPORTATION, H. M. Brinckerhoff
TRANSMISSION AND DISTRIBUTION, Edward B. Meyer

A. I. E. E. REPRESENTATION

(The Institute is represented on the following bodies; the names of the representatives may be found in the January issue of the JOURNAL and will be published again in the June issue.)

COUNCIL OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE
AMERICAN BUREAU OF WELDING
AMERICAN COMMITTEE ON ELECTROLYSIS
AMERICAN ENGINEERING COUNCIL OF THE FEDERATED AMERICAN ENGINEERING SOCIETIES
AMERICAN ENGINEERING STANDARDS COMMITTEE
BOARD OF TRUSTEES, UNITED ENGINEERING SOCIETY
ENGINEERING FOUNDATION BOARD
FRANCO-AMERICAN ENGINEERING COMMITTEE
JOHN FRITZ MEDAL BOARD OF AWARD
LIBRARY BOARD, UNITED ENGINEERING SOCIETY
ELECTRICAL COMMITTEE, NATIONAL FIRE PROTECTION ASSOCIATION
ENGINEERING DIVISION, NATIONAL RESEARCH COUNCIL
U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ILLUMINATION COMMISSION
U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION
COMMISSION OF WASHINGTON AWARD

A. I. E. E. SECTIONS AND BRANCHES

A complete list of the 42 Sections and the 67 Student Branches of the Institute with the names of the chairmen and secretaries, may be found in this issue and will be published again in the June issue.

LIST OF SECTIONS

Name	Chairman	Secretary
Akron	H. C. Stephens	R. B. Fisher, 5 Cyril Terrace, Akron, O.
Atlanta	J. E. Mellett	H. N. Pye, Box 1743, Atlanta, Ga.
Baltimore	Douglas Burnett	Vern E. Alden, 1905 Lexington Building, Baltimore, Md.
Boston	Lewis W. Abbott	F. S. Dellenbaugh, M. I. T., Cambridge, Mass.
Chicago	M. M. Fowler	E. H. Bangs, 212 W. Washington St., Chicago, Ill.
Cincinnati	J. D. Lyon	Leo Schirtzinger, 710 Traction Bldg., Cincinnati, O.
Cleveland	I. H. Van Horn	G. B. Schneeberger, Cleveland Elec. Illuminating Co., Cleveland, O.
Connecticut	C. F. Scott	A. E. Knowlton, Dunham Laboratory, Yale University, New Haven, Conn.
Denver	B. C. J. Wheatlake	R. B. Bonney, 603 Wyoming Bldg., Denver, Colo.
Detroit-Ann Arbor	A. S. Albright	E. L. Bailey, 707 Ford Bldg., Detroit, Mich.
Erie	C. H. Schum	P. B. Mansfield, Lawrence Park, Erie, Pa.
Fort Wayne	R. H. Chadwick	A. B. Campbell, General Electric Co., Ft. Wayne, Ind.
Indianapolis-Lafayette	D. C. Pyke	J. W. Hannon, Telephone Bldg., Indianapolis, Ind.
Ithaca	J. G. Pertsch, Jr.	G. F. Bason, Cornell University, Ithaca, N. Y.
Kansas City	C. J. Larsen	Glenn O. Brown, K. C. Power Co., Kansas City, Mo.
Lehigh Valley	Charles Hodge	H. G. Harvey, Penna. Utilities Co., Easton, Pa.
Los Angeles	Herbert H. Cox	J. N. Kelman, 1650 Naud St., Los Angeles, Cal.
Lynn	F. J. Rudd	D. F. Smalley, General Electric Co., West Lynn, Mass.
Madison	C. B. Hayden	H. M. Crothers, Univ. of Wisconsin, Madison, Wis.
Milwaukee	F. J. Mayer	P. B. Harwood, Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Minnesota	W. T. Ryan	F. A. Otto, 639 Holly Ave., St. Paul, Minn.
New York	Farley Osgood	H. A. Pratt, 165 Broadway, New York, N. Y.
Oklahoma	F. W. Insull	A. D. Stoddard, Box 382 Bartlesville, Okla.
Panama	R. D. Prescott	M. P. Benninger, Box 174, Balboa Heights, C. Z.
Philadelphia	P. H. Chase	R. B. Mateer, Phila. Elec. Co., 1000 Chestnut St., Philadelphia, Pa.
Pittsburgh	H. W. Smith	E. C. Stone, Duquesne Light Co., 435 6th Ave., Pittsburgh, Pa.
Pittsfield	I. H. Sclater	A. C. Stevens, General Electric Co., Pittsfield, Mass.
Portland, Ore.	W. C. Heston	D. W. Proebstel, Portland Ry. Lt. & Pr. Co., Portland, Ore.
Providence	Nicholas Stahl	F. N. Tompkins, Brown Univ., Providence, R. I.
Rochester	Sidney Alling	A. M. Stetler, Aluminum Co. of America, Granite Bldg., Rochester, N. Y.
St. Louis	C. C. Robinson	J. M. Chandler, 1827 Pine St., St. Louis, Mo.
San Francisco	W. P. L'Hommedieu	A. G. Jones, 809 Rialto Bldg., San Francisco, Cal.
Schenectady	S. H. Blake	C. W. Fick, General Electric Co., Schenectady, N. Y.
Seattle	J. P. Growdon	E. S. Code, 1400 Alaska Bldg., Seattle, Wash.
Spokane	L. J. Pospisil	H. L. Melvin, Washington Water Power Co., Spokane, Wash.
Syracuse	E. T. Moore	Elmer E. Strong, 614 City Bank Bldg., Syracuse, N. Y.
Toledo	G. Southern	Max Neuber, 1257 Fernwood Ave., Toledo, O.
Toronto	W. P. Dobson	P. A. Borden, 8 Strachan Ave., Toronto, Ont.
Urbana	E. H. Waldo	H. A. Brown, Univ. of Illinois, Urbana, Ill.
Utah	P. P. Ashworth	C. R. Higson, Utah Power & Light Co., Salt Lake City, Utah
Vancouver	John R. Read	F. W. McNeill, Canadian General Elec. Co., Vancouver, B.C.
Washington, D. C.	A. R. Cheyney	W. A. E. Doying, Panama Canal Commission, Washington, D.C.
Worcester	G. M. Hardy	Dean J. Locke, 125 Salisbury St., Worcester, Mass.

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LIST OF BRANCHES

Name and Location	Chairman	Secretary
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Alabama, Univ. of, University, Ala.	D. H. Davis	W. W. Bauder
Arizona, Univ. of, Tucson, Ariz.	J. Mellen	H. W. Holt
Arkansas, Univ. of, Fayetteville, Ark.	J. W. Booker	B. R. Askew
Armour Inst. of Tech., Chicago, Ill.	R. P. Burns	L. E. Grube
Brooklyn Poly. Inst., Brooklyn, N. Y.	H. Ladner	O. Engstrom
Bucknell Univ., Lewisburg, Pa.	F. T. Tingley	J. A. Ammerman
California Inst. of Tech., Pasadena, Cal.	O. R. Bulkley	L. J. Wells
California, Univ. of, Berkeley, Cal.	F. A. Polkinghorn	S. R. Ruby
Carnegie Inst.of Tech., Pittsburgh, Pa.	E. A. Brand	H. W. Bryan
Case School of Applied Science, Cleveland, O.	M. A. Hyde, Jr.	O. Henderson
Cincinnati, Univ. of, Cincinnati, O.	J. R. Petree	C. B. Hoffmann
Clarkson Coll.of Tech., Potsdam, N.Y.	R. L. Conboy	F. H. Fults
Clemson Agri. College, Clemson College, S. C.	J. R. Reardon	W. M. Clatworthy
Colorado State Agri. Coll., Ft. Collins, Colo.	P. Garrett	F. Ayres
Colorado, Univ. of, Boulder, Colo.	T. D. Sylvester	F. B. Doolittle
Cooper Union, New York	W. A. Colledge	A. L. Duna
Drexel Institute, Philadelphia, Pa.	D. Buchanan	R. E. Sidwell
Georgia School of Tech., Atlanta, Ga.	C. D. LeBey	E. V. Wallace
Iowa State College, Ames, Ia.	C. H. Hoper	G. L. Seaton
Iowa, Univ. of, Iowa City, Ia.	E. Paintin	P. F. Bowman
Kansas State College, Manhattan, Kans.	L. O. Sinderson	K. C. Frank
Kansas, Univ. of, Lawrence, Kans.	E. S. Miner	C. A. Harris
Kentucky, Univ. of, Lexington, Ky.	T. M. Riley	R. H. Craig
Lafayette College, Easton, Pa.	G. A. Moore	P. J. Brown
Lehigh Univ., South Bethlehem, Pa.	E. F. DeTurk	W. F. Tait
Lewis Institute, Chicago, Ill.	E. Millison	E. R. Lindberg
Maine, Univ. of, Orono, Me.	F. Blake	C. R. Lappin
Massachusetts Inst. of Tech., Cambridge, Mass.	L. R. Culver	L. W. Codding
Michigan Agri. Coll., East Lansing, Mich.	E. A. Pryce	J. G. Lauffer
Michigan, Univ. of, Ann Arbor, Mich.	F. D. Johnston	A. J. Martin
Milwaukee, Engg. School of, Milwaukee, Wis.	B. A. Bovee	L. F. Berg
Minnesota, Univ. of, Minneapolis, Minn.	H. A. Dahl	E. S. Bjonerud
Missouri, Univ. of, Columbia, Mo.	A. C. Lanier	F. W. Hubbard
Montana State Coll., Bozeman, Mont.	W. W. Husemeyer	R. D. Sloan
Nebraska, Univ. of, Lincoln, Neb.	O. J. Ferguson	O. E. Edison
North Carolina State College, West Raleigh, N. C.	E. E. Inscoe	O. L. Bradshaw
North Carolina, Univ. of, Chapel Hill, N. C.	R. M. Casper	R. G. Koontz
North Dakota, Univ. of University, N. D.	E. L. Hough	S. W. Winje
Notre Dame, Univ. of, Notre Dame, Ind.	J. R. Fitzgerald	W. L. Shilts
Ohio Northern Univ., Ada, O.	L. A. Kille	I. W. Knapp
Ohio State Univ., Columbus, O.	W. M. Kellogg	O. McGinnis
Oklahoma A. & M. Coll., Stillwater, Okla.	C. S. Folk	I. T. Knight
Oklahoma, Univ. of, Norman, Okla.	W. Seifert	R. E. Thornton
Oregon Agri. Coll., Corvallis, Ore.	W. D. Olson	C. T. Hurd
Pennsylvania State College, State College, Pa.	H. F. Pearson	J. H. Warner
Pennsylvania, Univ. of, Philadelphia, Pa.	E. M. Heidelbaugh	J. B. Clothier, Jr.
Pittsburgh, Univ. of, Pittsburgh, Pa.	C. A. Anderson	A. F. Robert
Purdue Univ., Lafayette, Ind.	N. C. Pearcy	F. R. Finehout
Rensselaer Poly. Inst., Troy, N. Y.	W. J. Williams	L. S. Inskip
Rose Poly. Inst., Terre Haute, Ind.	F. M. Stone	C. B. Wilson
Rutgers College, New Brunswick, N. J.	H. Goldsmith	T. B. Brown
Southern California, Univ. of, Los Angeles, Cal.	R. H. Cockfield	E. B. Heath
Stanford Univ., Stanford University, Cal.	H. E. Becker	V. Marquis
Swarthmore Coll., Swarthmore, Pa.	S. T. McAllister	E. Palmer
Syracuse Univ., Syracuse, N. Y.	E. A. Ryan	A. P. Fugill
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Texas, Univ. of, Austin, Tex.	C. H. Marshall	F. J. Domingues
Virginia Military Inst., Lexington, Va.	W. P. Venable	R. P. Martin
Virginia Poly. Inst., Blacksburg, Va.	D. P. Minichan	T. F. Cofer
Virginia, Univ. of, University, Va.	M. H. Morgan	N. W. Brown
Washington, State Coll. of, Pullman, Wash.	E. Johnson	O. J. Ball
Washington Univ., St. Louis, Mo.	F. W. Schramm	E. H. Burgess
Washington, Univ. of, Seattle, Wash.	V. A. Travis	C. A. Brokaw
West Virginia Univ., Morgantown, W. Va.	H. Chandler	W. D. Stump
Wisconsin, Univ. of, Madison, Wis.	R. H. Herrick	J. W. Smart
Yale Univ., New Haven, Conn.	E. R. Zeitz	S. S. Bailey

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DIGEST OF CURRENT INDUSTRIAL NEWS

NEW CATALOGS AND OTHER TRADE PUBLICATIONS

Mailed to interested readers by issuing companies.

Thrust Bearings.—Catalog C, 72 pp. Hydroelectric and marine applications. Kingsbury Machine Works, Philadelphia.

Combustion Recording Equipment.—Bulletin 112, 12 pp. For checking heat losses. Uehling Instrument Co., Paterson, N. J.

Forging and Heating Furnaces.—Bulletin 241, 12 pp. W. S. Rockwell Co., 50 Church St., New York.

Ground Rods.—Data Sheet and Tables. Describes copperweld nails and ground rods. Copper Clad Steel Co., Rankin, Pa.

Boiler Practise in Textile Mills.—Bulletin 51, 32 pp. Illustrating installations of Heine boilers. Heine Boiler Co., St. Louis, Mo.

Ferro-Alloys and Metals.—Catalog, 26 pp. Chromium, manganese, silicon, zirconium. Electro Metallurgical Sales Corp., 30 East 42nd St., New York.

Ovens.—Catalog, 34 pp. Annealing, core, drying, enameling, etc. ovens, for gas, electric, oil or steam heating. The Paul Maehler Co., 2210 West Lake St., Chicago.

Powdered Fuel Systems.—Bulletin 4, 40 pp. Describes a complete service for installing preparatory, storage, conveying, firing and furnace equipment. Grindle Fuel Equipment Co., Harvey, Ill.

Small Motors.—"Little Motor Talks," No. 1 (Brush Mounting). A series of leaflets each describing one phase of small motor construction and operation. Rochester Electric Products Corp., Rochester, N. Y.

Renewable Fuses.—Booklet 4472, 16 pp. Describes a recently developed renewable fuse for protection of low-voltage circuits up to 600 volts, both a-c. and d-c. Westinghouse Elec. & Mfg. Co., East Pittsburgh.

Converter.—Bulletin 130, 16 pp. Wagner White Light Converter for motion picture projection. A self-contained generating unit for converting alternating current into direct current. Wagner Electric Mfg. Co., St. Louis.

Evaporator Systems.—Bulletin 360, 8 pp. Describes the application of Reilly evaporators self-scaling for purification of boiler feed water by distillation. The Griscom-Russell Co., 90 West St., New York.

Megger Testing Sets.—Catalog J-985, describing Megger and Bridge Megger testing sets for determining insulation resistance of electrical machinery, wires and cables, etc. James G. Biddle, 1211 Arch St., Philadelphia.

Power Transmission Coupling.—Bulletin. Describes Cord Disk coupling for connecting power transmitting or receiving machinery, such as electrical units, hydraulic, steam, turbine and other applications. The Climax Motor Devices Co., Chagrin Falls, O.

Diesel Engine.—Vol. 8, No. 3, "Lubrication." Describes construction, operating features and lubrication of 1000 H. P. Diesel engine installed in captured German submarine. The Texas Company, 17 Battery Place, New York.

Welding Rods and Electrodes.—Catalog 500, 40 pp. For oxy-acetylene and electric welding. Describes manufacture and proper application. Contains American Welding Society Specifications for Electrodes and Gas Welding Rods; metallurgy of iron and steel, comparative tables and other useful information. Page Steel & Wire Co., Bridgeport, Conn.

Conduit Fitting.—Bulletin. New Type FB entrance fitting for 2½" and 3" conduit, consisting of three parts, a cover, hub and plate which will hold 2, 3 or 4 porcelain bushings. By changing the relative positions of the hub and cover the fitting may be used on either horizontal or vertical pipe. Killark Electric Mfg. Co., St. Louis.

Slate for Electrical Uses.—Chapter 12 of series on Structural Slate. Pamphlet, linen bound, 44 pp. Contains the results of a series of exhaustive tests made by Lehigh University to establish data and information relative to physical, chemical and electrical characteristics of slate, also tentative specifications. Illustrates quarrying, development and application of slate to electrical equipment. The Structural Slate Co., Pen Argyl, Pa.

Outdoor Lighting Control.—"Engineer's Reference Book." Deals comprehensively with all phases of outdoor lighting control from the power house by means of the R. C. O. C. system of remote control. Includes typical plans and data for solving problems connected with control of constant current transformers, bridge, tunnel and subway lights, large signs, and a wide variety of other applications to suit local conditions. South Bend Current Controller Co., South Bend, Ind.

Transformers.—Catalog 215, 48 pp. Contains a brief history of the transformer, and the issuing company, and describes in non-technical language the functions of transformers. The principal features of such apparatus are discussed, including insulation, core and copper loss, regulation, parallel operation, taps, etc. Effects of overloading, underloading, overvoltage and undervoltage are shown. The catalog includes complete rules for correct transformer operation and detailed description of construction of all sizes and types. Moloney Electric Co., St. Louis.

CHANGES IN THE INDUSTRY

Heine Boiler Company, St. Louis.—The word "Safety" has been dropped from the name of this firm.

Memco Engineering & Mfg. Co., Inc.—Transmission Line and Outdoor Substation Equipment. Have removed their office from 61 Broadway to Hudson Terminal Building, 30 Church St., New York.

Moloney Electric Company.—Transformers. H. C. Budd, formerly with the Canadian General Electric Co. of Winnipeg, has joined the sales force of the Moloney Electric Company of Canada, Ltd., with headquarters at the main sales office, 501 York Bldg., Toronto.

Combustion Engineering Corporation, New York. The Power Plant Equipment Co., 1002 Coca-Cola Building, Kansas City, Mo. has been appointed sales agent for eastern Kansas, eastern Nebraska, Western Arkansas and Western Missouri.

A new branch office has been opened at 1137 Guardian Building, Cleveland, in charge of Mr. Frank Henderson.

Roller-Smith Company, New York. The following changes have been made in the sales organization: The Perkins-LeNoir Co., who formerly represented the Roller-Smith Co. in Philadelphia and Baltimore has been succeeded by Esherick & Hoyle, Otis Building, Philadelphia and J. E. Perkins, 113 E. Franklin St., Baltimore, who will handle the Roller-Smith Company's line of electrical instruments, meters and circuit-breakers in their respective territories.